Spawner - Recruit Data for Spring and Summer Chinook Salmon Populations in Idaho, Oregon, and Washington

R. C. P. Beamesderfer, H. A. Schaller, M. P. Zimmerman

Oregon Department of Fish and Wildlife
Post Office Box 59, Portland, Oregon 97207

C. E. Petrosky

Idaho Department of Fish and Game
Post Office Box 25, Boise, Idaho 83707

O. P. Langness and L. LaVoy

Washington Department of Fish and Wildlife
Post Office Box 999, Battle Ground, Washington 98604

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Abstract

This report reviews and updates spawner and recruit data for Snake and Columbia River spring/summer chinook stocks; develops data for index stocks subjected to varying levels of human-induced mortality from hydropower, habitat, and hatchery effects; provides consistent data based on standard methods and spreadsheets; and identifies index stocks, data sources, calculation methods, and assumptions. Numbers of spawners and returning recruits to the mouth of the Columbia River were estimated for the aggregate stocks returning to tributaries upstream from Bonneville and Ice Harbor dams, and for 22 index populations from the Salmon, Imnaha, Grande Ronde, Methow, Entiat, Wenatchee, John Day, Deschutes, Klickitat, and Wind River subbasins using spawning ground surveys, age frequencies, mainstem and tributary harvest rates, and mainstem conversion rates for upstream passage of adults available from the 1940's to present. Index populations accounted for more than half (55%) of the aggregate spring run of natural spawners above Bonneville Dam. Spawners, recruits, and recruits per spawner were all extremely variable over the period of record and were weakly correlated with each other and with year. Further exploration of individual population responses stratified by area and time may help determine the underlying causes of variation and trend in spawners, recruits, Ln(recruits/spawner), and Ln(recruits/spawner) versus spawners. Accurate projections of future abundance, risk of extinction, and probability of recovery should incorporate the observed variability.

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Introduction

Time series of adult abundance data are a key component of many analyses of the status, limiting factors, management practices, and future prospects for salmon in the Columbia and Snake rivers (Konkel and McIntyre 1987; Martin et al. 1987). For instance, salmon stock productivity and survival rates can be estimated from run reconstructions which estimate numbers of spawners and recruits from each brood year (Ricker 1954, 1975; Beverton and Holt 1957). Analyses of spawner-recruit data provide one method for assessing the cumulative effects of harvest, hatchery production, habitat changes, and hydroelectric development on anadromous fish (Martin et al. 1987). Spawner-recruit data is especially useful for measuring density independent productivity in assessments of the effects of development and operation of the Federal Columbia River Power system. Risk assessments and other modeling approaches used to compare the effects of all anthropogenic sources of mortality on salmon survival and recovery are calibrated with spawner-recruit data (BRWG 1994, Paulsen et al. 1993). Time series of spawner and recruit data from stocks throughout the Columbia River Basin may provide an important inferential basis for hypothesis tests regarding distribution of the mortality throughout the life cycle (Barnthouse et al. 1994). Finally, cohort replacement rates based on recruitment-stock ratios can be used to identify “harvestable surpluses” (Lindsay et al. 1986) and also define criteria for delisting endangered Snake River salmon stocks (NMFS 1995).

Productivity of a salmon population for a specified time period is defined as the natural log of the ratio of recruits to spawners, in the absence of density dependent mortality (Neave 1953). Productivity can be measured as the intercept, or "a" value from Ricker (1975, equation 11.15). Survival rate indices provide a time series of density independent mortality estimates through deviations of observed recruit per spawner ratios from those predicted by the fitted stock recruitment function (predicted R/S) for a specified time period (Schaller et al. 1996).

Spring/summer chinook run reconstructions have been reported by: Barton (1979) for an aggregate stock, Lindsay et al. (1986) for John Day River, OR; Lindsay et al. (1989) and Olsen (1992) for Warm Springs River, OR; Petrosky (1991) for Marsh Creek, ID; and Petrosky and Schaller (1992) for several Snake and Columbia River stocks examined with an empirical life cycle model. The latter reconstructions were also used to determine requirements for Snake River salmon survival and recovery by the interagency Biological Requirements Work Group (BRWG 1994) during IDFG, et al. v. NMFS, et al. negotiations.

In this report we: 1) review and update spawner and recruit data for selected Idaho, Oregon, and Washington spring and summer chinook stocks; 2) develop data for stocks subjected to varying levels of human-induced mortality from hydropower, habitat, and hatchery effects; 3) provide consistent data based on standard methods and spreadsheets; and 4) identify index stocks, data sources, calculation methods, and assumptions. Interpretation of results is limited in this report because these data were developed as a baseline for other analyses in the Process to Analyze and Test Hypotheses (PATH) and in anadromous fish monitoring under the NMFS Snake River Salmon Recovery and NPPC Fish and Wildlife programs (Schaller et al. 1996, Deriso et al. 1996, Paulsen 1996). Spawner and recruit data for index stocks will be stored and distributed through the regional StreamNet information network (Allen et al. 1994).

Chinook Salmon Life History

Spring, summer, and fall runs of chinook salmon inhabit the Columbia Basin. Columbia Basin spring chinook salmon and Snake River summer chinook salmon possess stream-type life histories where juveniles reside in freshwater for at least 1 year and adults return to freshwater in spring and summer several months before spawning (Healy 1991). Columbia Basin fall chinook and upper Columbia River summer chinook possess ocean-type life histories in which juveniles leave freshwater during their first summer and adults spawn soon after entering freshwater in summer and autumn. Stream-type chinook typically spawn in small headwater tributaries throughout the Columbia basin (Fulton 1968). Ocean-type chinook typically spawn in the mainstem Columbia and Snake Rivers and the lower reaches of large tributaries. This report includes run reconstructions only for stream-type chinook including spring chinook and Snake River summer chinook populations.

Spring and summer runs of Columbia basin chinook salmon are distinguished by time of entry of adults into freshwater - typically March through May for spring-run populations and June through July for summer-run populations (Figure 1). Spring-run fish spawn from August to early October. Snake River summer-run fish spawn during September. An early-migrating group of summer run populations spawns primarily in Idaho's Salmon River drainage. A later-migrating group of summers is destined for Columbia River tributaries upstream from Priest Rapids Dam (ODFW and WDFW 1995). Juveniles of both runs emerge from the gravel from January to April. Spring and early summer run populations rear in freshwater through the following winter and migrate to the ocean as 1-year-old smolts, primarily during April through June at fork lengths averaging 100-160 mm (FPC 1994).

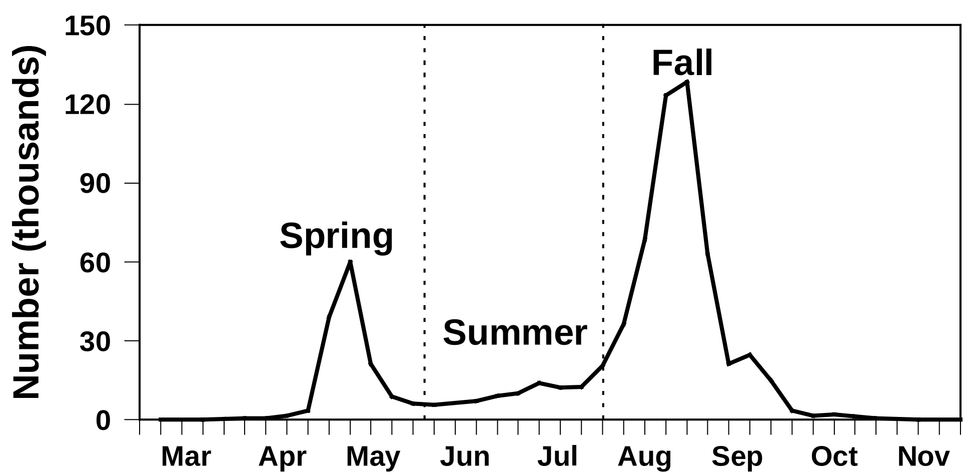

FIGURE 1. Run timing of chinook salmon to the Columbia River in 1938 based on Bonneville Dam counts and estimated harvest between the mouth and Bonneville Dam (Rich 1943).

Adult spring and summer chinook salmon return to freshwater at ages 2 to 6 with most fish returning as 4- and 5-year olds. Adults typically move upstream quickly until they reach spawning tributaries. In tributaries, adults often hold for several months in large deep pools before spawning. All adults die soon after spawning.

Total Columbia River returns of spring and summer chinook salmon destined for tributaries upstream from Bonneville Dam have ranged, during the last 50 years, from a high in 1957 of 460,000 to a low in 1995 of 29,438 (Figure 2). Hatchery-reared fish have made up an increasing proportion of returns since 1980 and now comprise 60-80% of the run as numbers of wild fish have continued to decline. The increase in hatchery production corresponds to mitigation programs designed to compensate for loss of salmon production due to hydropower development including complete blockage of some areas. Commercial, sport, and tribal fisheries operating in the Columbia River mainstem between the mouth and McNary Dam at Rkm 470 typically harvested 40-80% of upriver spring chinook salmon and 30-50% of upriver summer chinook salmon until 1975 when fisheries were severely restricted to protect weak stocks (ODFW and WDFW 1995). Small numbers of spring chinook salmon were also harvested in the mainstem Columbia River upstream from the mouth of the Snake River. Few spring or stream-type summer chinook salmon are or have been taken in ocean fisheries (Berkson 1991). Most terminal sport and tribal fisheries for spring and summer chinook salmon have been closed since the 1970s.

Columbia River salmon populations have been subject to significant changes in tributary, mainstem, and ocean habitat conditions during the last century. Many tributary spawning and rearing habitats have suffered from the cumulative effects of land use practices which are detailed for each population in later sections of this report. Mainstem migration conditions have been drastically altered by dam construction (Figure 3). In addition, large-scale variation in climate and weather have affected ocean productivity and fish survival (Beamish 1993).

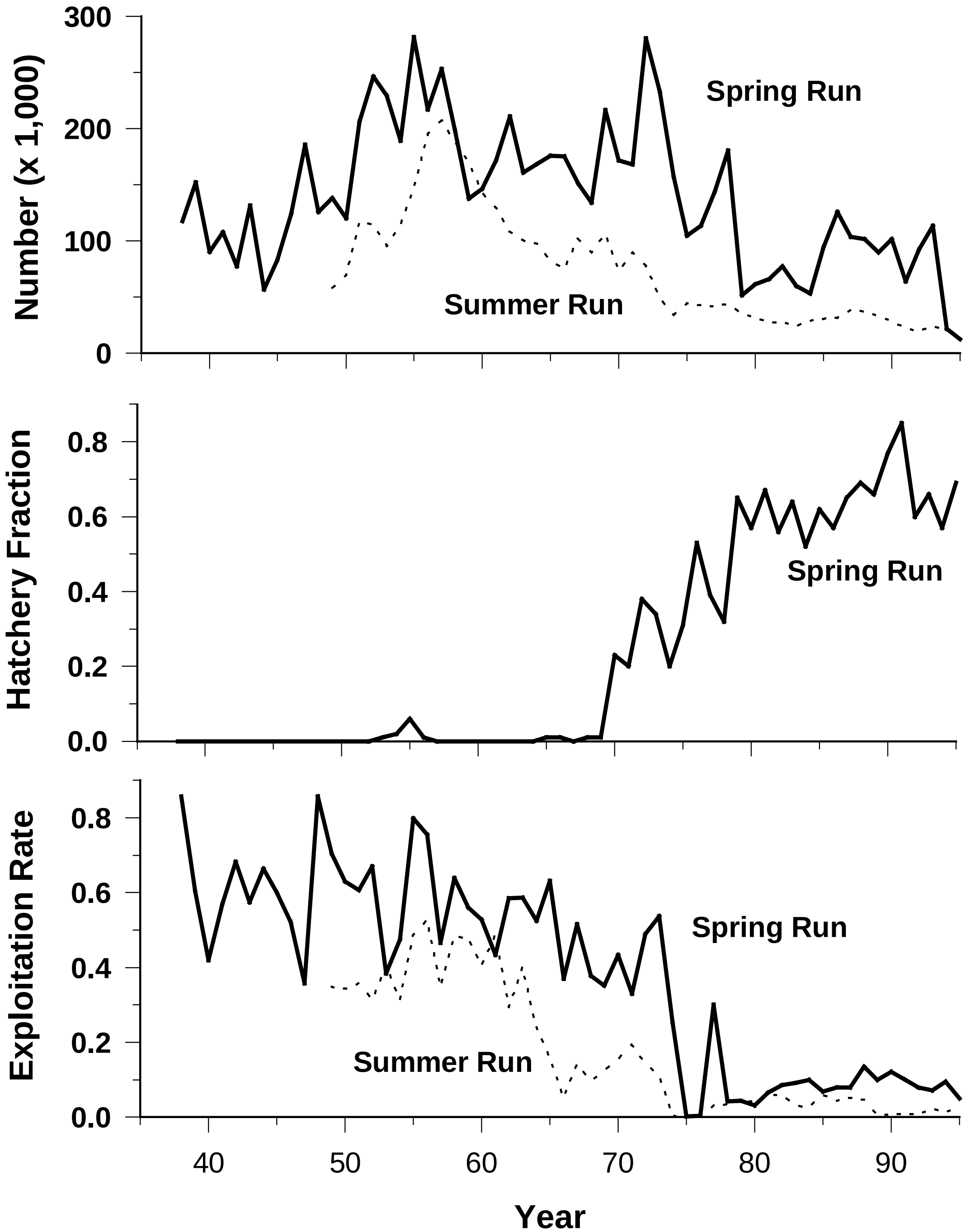

FIGURE 2. Abundance, hatchery fraction, and exploitation rate of upriver chinook salmon in the Columbia River, 1939-present. Number is total based on Bonneville Dam count plus harvest in mainstem fisheries downstream from McNary Dam. Exploitation includes mainstem fisheries between the Columbia River mouth and McNary Dam (ODFW and WDFW 1995).

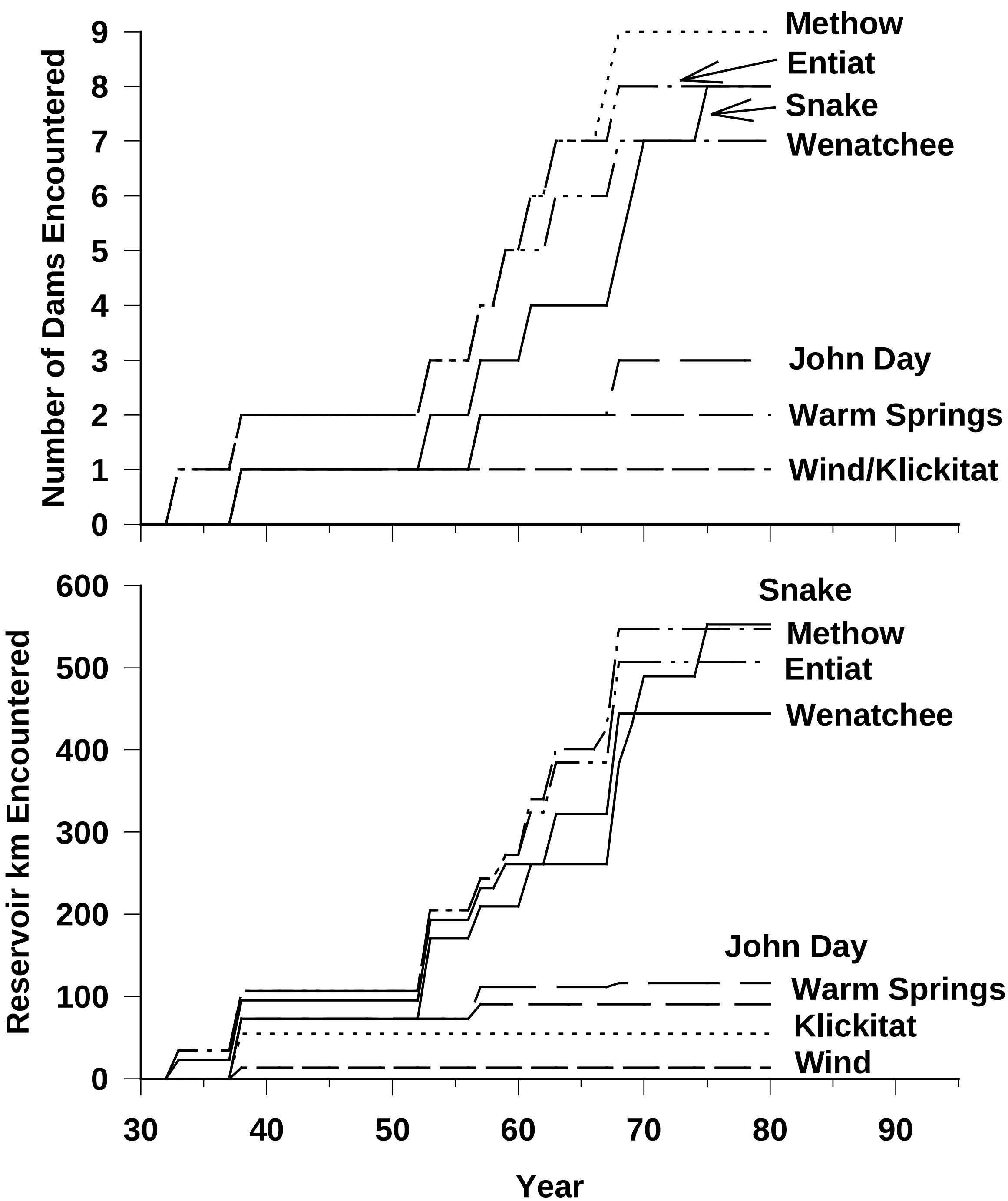

FIGURE 3. Number of dams and reservoir distances encountered by migrant spring and summer chinook salmon populations since 1930.

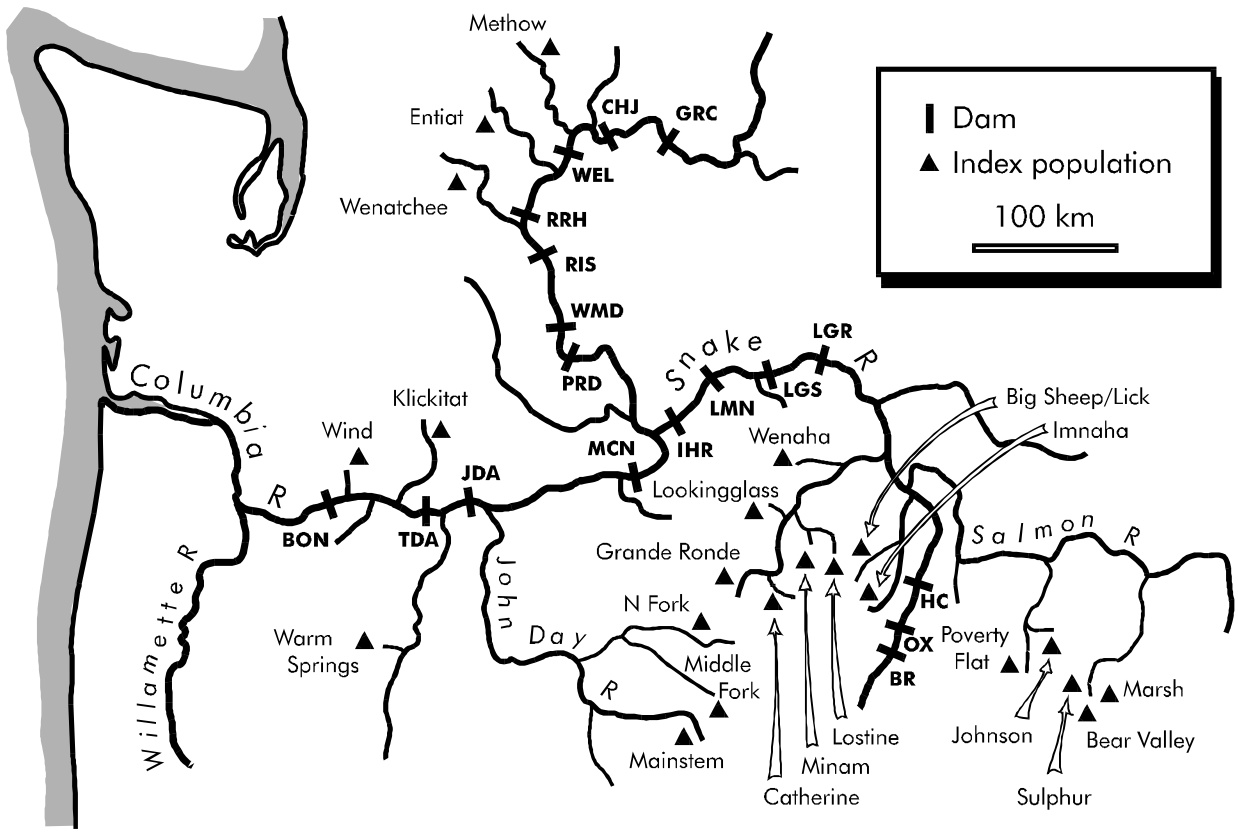

FIGURE 4. Locations of spring and summer chinook salmon index stocks for Idaho, Oregon, and Washington portions of the Columbia River basin.

Index Areas

This report includes data for an aggregate upper Columbia and Snake River group, an aggregate Snake River group, and 22 populations of spring and summer chinook salmon from rivers throughout Idaho, Oregon, and Washington (Figure 4, Table 1).

Dam Aggregates

One aggregate group includes all spring chinook populations spawning in Columbia and Snake River tributaries upstream from Bonneville Dam. A second aggregate group includes all spring chinook populations spawning in Snake River tributaries upstream from Ice Harbor Dam. Changes in spawners, recruits, Ln(recruits/spawner), and Ln(recruits/spawner) versus spawners of this aggregate group include changes within individual populations like those identified for index populations in this report and also loss of individual populations, for instance, dam construction which blocked access to portions of the historic range.

TABLE 1. Index populations of wild spring and summer chinook salmon (age 1 migrants) in several Oregon and Washington river subbasins.

Subbasin, population	Run[1]	Years of data[2]	Dams passed	Ocean Distance (km)[3]	Elev-ation (m)[4]	Avail. Habitat (km)	Habitat quality	Hatchery influence
Aggregate								
Bonneville	Spring	1939-95	1 - 9	235	--	--	Variable	Variable
Snake River	Spring	1962-95	1 - 8	540	--	--	Variable	Variable
Middle Fork Salmon								
Bear Valley/Elk	Spring	1957-95	8	1,320	1,980	53	Poor	Low
Marsh	Spring	1957-95	8	1,330	2,020	24	Good	Low
Sulphur	Spring	1957-95	8	1,300	1,740	18	Good	Low
South Fork Salmon								
Poverty Flat	Summer	1957-95	8	1,130	1,310	28	Poor	Moderate
Johnson	Summer	1957-95	8	1,120	1,160	41	Fair	Moderate
Imnaha								
Mainstem	Spr/Sum	1949-95	8	880	1,270	65	Good	Moderate
Big Sheep/Lick	Spr/Sum	1964-95	8	895	1,170	44	Poor	Moderate
Grande Ronde								
Upper mainstem	Spring	1959-95	8	1,095	1,220	50	Fair	Moderate
Catherine	Spring	1953-95	8	1,060	1,110	44	Fair	Moderate
Lookingglass	Spring	1950-85[5]	8	930	860	23	Good	High
Lostine	Spring	1950-95[5]	8	965	1,350	39	Fair	Moderate
Minam	Spring	1954-95	8	950	1,250	30	Good	Moderate
Wenaha	Spring	1949-95[5]	8	880	810	44	Good	Moderate
Methow	Spring	1960-95	9	860	600	184	Fair	Moderate
Entiat	Spring	1955-95	8	810	500	23	Fair	Moderate
Wenatchee	Spring	1954-95	7	770	700	140	Fair	Moderate
John Day								
Upper mainstem	Spring	1959-95	3	770	1,130	23	Fair	Low
Middle Fork	Spring	1959-95	3	760	1,160	49	Fair	Low
N. Fork/Granite	Spring	1964-95	3	745	1,260	102	Good	Low
Deschutes								
Warm Springs	Spring	1969-95	2	470	740	68	Fair	Moderate
Klickitat	Spring	1966-95	1	370	500	90	Fair	Moderate
Wind	Spring	1970-95	1	270	300	20	Good	High

[1] *Spring and summer runs are distinguished by time of entry of adults into freshwater - typically March through May for spring-run populations and June through July for summer-run populations*
[2] *Run or spawner years.*
[3] *Distance from Columbia River mouth to lowermost limit of spawning.*
[4] *Average of elevations at lowermost and uppermost limits of spawning.*
[5] *Incomplete time series.*

Middle Fork Salmon

Middle Fork Salmon River (MFSR) index areas for spring chinook salmon include Bear Valley and Elk creeks (combined), Marsh Creek, and Sulphur Creek (Figure 5). Other significant spawning areas for spring and summer chinook in the subbasin include Loon Creek, Camas Creek, Big Creek, the mainstem MFSR, and numerous smaller tributaries. The Middle Fork Salmon River (151 km long) is located in the uplands of the Idaho batholith, a mountainous region of erosive, granite soils. Meandering, low-gradient channels (C-channel type in Rosgen 1985) predominate throughout Sulphur Creek and the upper drainages of Bear Valley, Elk, and Marsh Creeks. Lower Bear Valley and Marsh creeks flow through canyons and then join to form the Middle Fork Salmon River. Sulphur Creek enters the Middle Fork Salmon River 16 km below the confluence of Marsh and Bear Valley creeks. Climate is characterized by long, cold winters and warm, dry summers, with 75% of the annual precipitation (64-152 cm/yr) falling as snow (Platts et al. 1986). Highland vegetation in the upper drainage is typically forest comprised of Engleman spruce, subalpine fir, and lodgepole pine. Valley floor vegetation is typically lodgepole pine, grasses, willows, and sedges. Most of the Middle Fork Salmon River subbasin is managed by the U. S. Forest Service and large portions are designated as wilderness. Lower Marsh Creek and the Sulphur Creek drainage are in the Frank Church River of No Return Wilderness. The Sulphur Creek drainage is accessible only by trail or aircraft.

Although most of the Middle Fork Salmon River drainage lies within undeveloped wilderness, portions have experienced habitat degradation from grazing, mining and other land use activities (Platts et al. 1986). Sheep were grazed intensively throughout the Bear Valley/Elk Creek drainage from about 1880 to 1916. Intensive cattle grazing began around 1900; between 1931 and 1971, some 1,300-1,600 cattle were grazed annually. Sheep have been grazed since the 1880s in the area between Bear Valley and Ketchum which includes the Marsh Creek drainage (Platts et al. 1986). Until recently, about 2.7 km of mainstem Marsh Creek received heavy grazing pressure from cattle, with the rest of the drainage (84 km) ungrazed or grazed by sheep (OEA 1987). Although the cattle-grazed reach of Marsh Creek comprised a small fraction of chinook spawning and rearing habitat, the pastures coincided with areas of concentrated chinook spawning. The Sawtooth National Recreation Area excluded cattle from the Marsh Creek drainage in 1993. Sulphur Creek has no history of cattle grazing; one small, fenced horse pasture is located at an outfitter ranch. Some concern was raised by D. Chapman during the IDFG, et al v. NMFS, et al. negotiations with respect to using Sulphur Creek as representative of wilderness conditions because of "slop-over" grazing from adjacent drainages (BRWG 1994). However, field observations by IDFG personnel since 1984 indicate that cattle rarely stray into the drainage - the last reported sighting was of two strays near the North Fork Sulphur Creek in 1984 (T. Holubetz, C. Petrosky, K. Plaster, IDFG, pers. comm.).

The Bear Valley/Elk Creek drainage has been roaded, with limited cutting of lodgepole pine for post-and-pole and firewood. The Marsh Creek drainage has been less affected by roads and has experienced very little timber harvest. The Sulphur Creek drainage is unroaded with no logging activities. A dredge mine operated in upper Bear Valley Creek from the late 1950s until 1960. Breaches of diversion canals at the abandoned site resulted in mass erosion during the 1960s, which continued at a lesser rate into the 1980s (Rowe et al. 1991). There are no irrigation diversions in Bear Valley, Elk, or Sulphur Creeks and no major ones downstream to the Snake

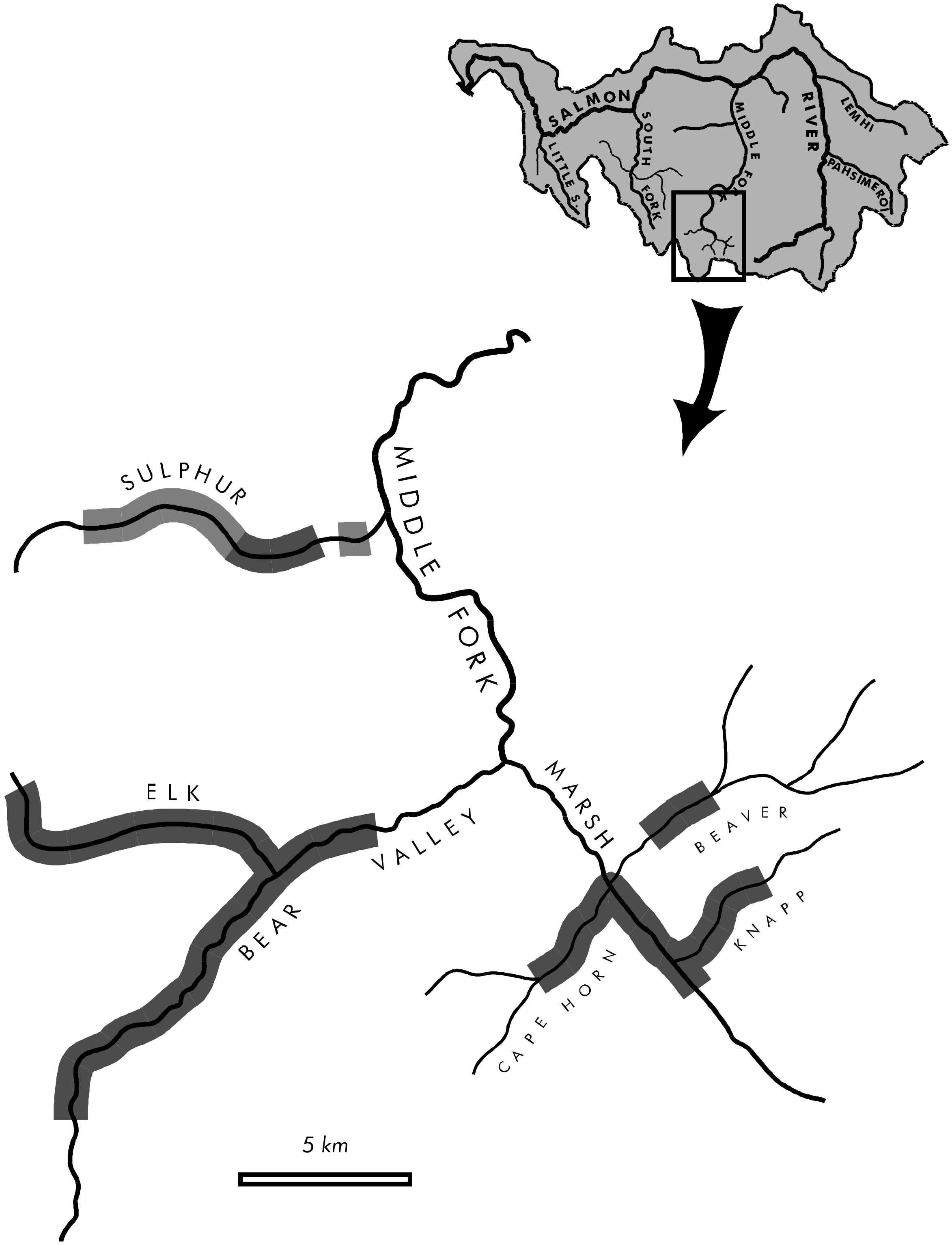

FIGURE 5. Spawning and index areas for spring chinook salmon in the Middle Fork Salmon River subbasin, Bear/Valley/Elk, Marsh, and Sulphur Creek populations. Index areas are denoted in dark gray and other significant spawning areas are denoted in light gray.

River. One small, screened irrigation diversion is located on Knapp Creek which is upstream from most of the spawning habitat in the Marsh Creek drainage. This diversion partially blocked adult salmon passage before modification by the Challis National Forest in 1987 through the Fish and Wildlife Program (Scully and Petrosky 1991; J. Andrews, USFS, pers. comm.). Habitat improvement projects were implemented in the 1980s in Bear Valley/Elk and Marsh Creeks under the Fish and Wildlife program to reduce sediment input from grazing, roads, and the Bear Valley Mine site, and to restore riparian and instream conditions (Andrews and Everson 1988; Rowe et al. 1991).

Surveys of instream and riparian habitat were completed throughout the upper Middle Fork drainage in 1985 and 1986 (OEA 1987, Appendix D in Petrosky and Holubetz 1987). The highest sediment levels and poorest streambank stability of those inventoried were found in the Bear Valley/Elk Creek drainage where surface sediment in C-channel sections averaged nearly 50%. The Marsh Creek drainage had localized sedimentation problems and decreased streambank stability caused by cattle grazing. Habitat indices in ungrazed and sheep-grazed areas of the Marsh Creek drainage were significantly better than in areas of heavy cattle use. Surface sediment in C-channel sections averaged 19% in the Marsh Creek drainage in 1985. Riparian and instream habitats in Sulphur Creek drainage were in excellent condition and streambank stability ratings were generally similar to those observed in ungrazed reaches of nearby streams. Surface sediment in C-channel sections averaged 25% in Sulphur Creek in 1986.

Summer water temperatures are suitable for rearing salmonids throughout the Middle Fork Salmon River drainage. High quality habitats for rearing and over-wintering exist in wilderness in the Middle Fork Salmon River downstream of Bear Valley/Elk Creek, Marsh, and Sulphur Creeks. Large pools suitable for resting by returning adult salmon are common in all drainages of the upper Middle Fork Salmon River.

The entire Middle Fork Salmon River drainage is managed for wild, native spring and summer chinook salmon and wild, native steelhead (Kiefer et al. 1992). No hatcheries are located in the Middle Fork drainage, no anadromous salmonids have been released into Bear Valley, Elk, or Sulphur creeks, and no wild fish have been removed for hatchery broodstock (IDFG data files). Only one release of hatchery chinook salmon has been made into the Middle Fork Salmon River drainage (Matthews and Waples 1991); in 1975, University of Idaho researchers released 22,000 nonindigenous spring chinook fry into Cape Horn Creek, a Marsh Creek tributary. Sport harvest on wild chinook has been closed since 1979 in the MFSR. MFSR spring chinook were previously harvested in sport fisheries in the tributaries, mainstem MFSR and in the Salmon River. Horner and Bjornn (1981) estimated that, on average, 24% of Idaho spring/summer chinook sport harvest occurred in the MFSR drainage from 1959 to 1978. Tribal harvest also occurred on MFSR chinook through the late 1970s.

South Fork Salmon

Index populations detailed in this report for the South Fork Salmon River (SFSR) include the Poverty Flat area (lower SFSR) and Johnson Creek (Figure 6). Other significant breeding units in the subbasin include upper SFSR (including Stolle Meadows); Secesh River; and East Fork of the SFSR (BRWG 1994). The South Fork Salmon River, 160 km long, is located in the uplands

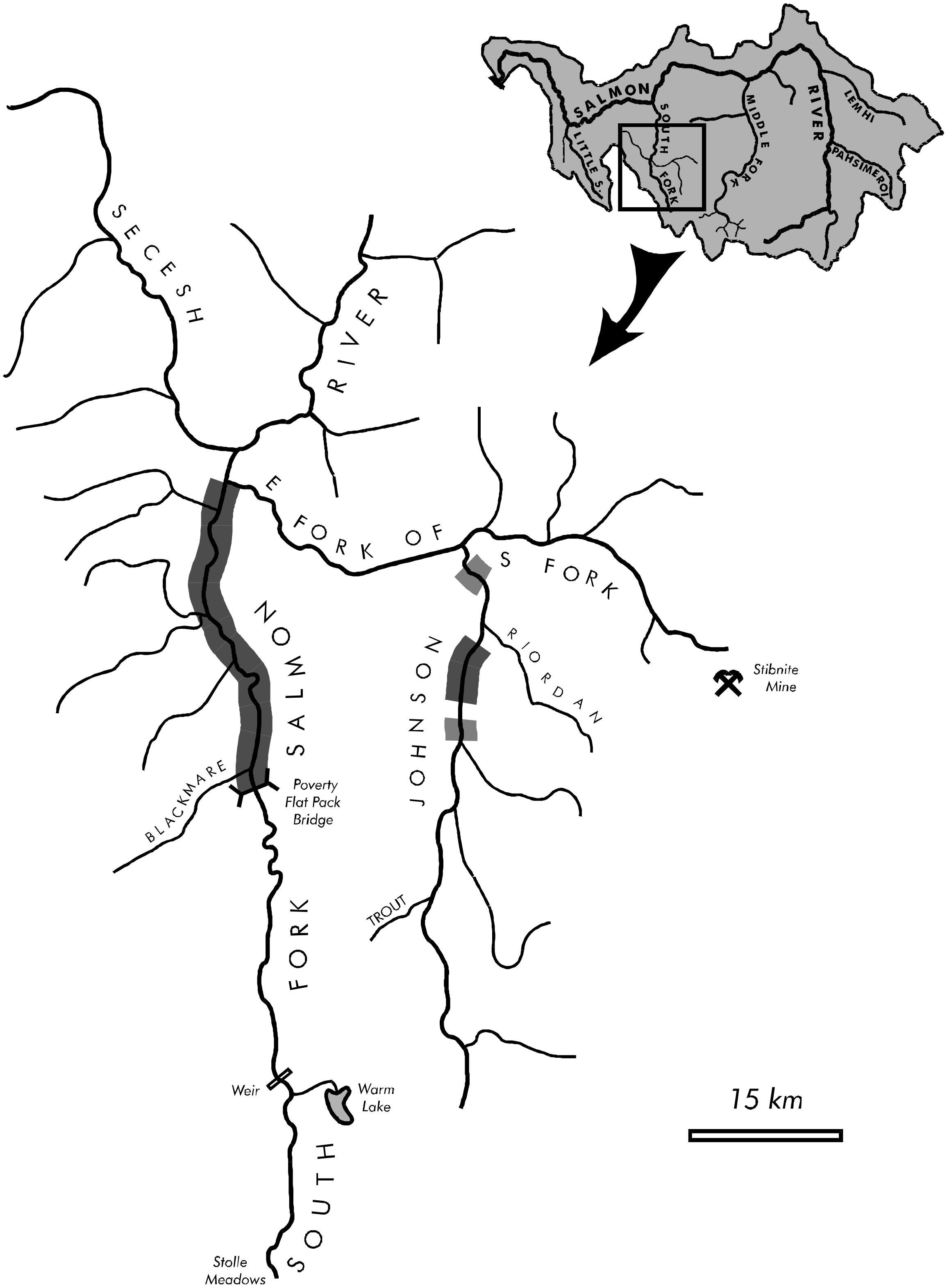

FIGURE 6. Spawning and index areas for summer chinook salmon in the South Fork Salmon River subbasin, Poverty Flat, and Johnson Creek populations. Index areas are denoted in dark gray and other significant spawning areas are denoted in light gray. Note: spawning areas for populations from upper South Fork Salmon, East Fork South Fork Salmon, and Secesh rivers are not shown.

of the Idaho batholith, a mountainous region of erosive, granite soils. The Poverty Flat spawning area (RKM 88) is a lower gradient reach on the mainstem SFSR. The majority of chinook spawning in Johnson Creek occurs in a lower gradient section near the mouth (RKM 9). Annual precipitation ranges from 76 to 154 cm throughout the watershed (Platts et al. 1989), mostly as snow fall. Both index areas are characterized by steep, forested slopes predominated, by Ponderosa pine. Land ownership is primarily U. S. Forest Service.

The South Fork Salmon River and Johnson Creek drainages have been heavily degraded by land management activities, including road construction, logging and (in the upper drainage) cattle grazing (Thurow 1987, Kiefer et al. 1992). Concern about damage to salmon habitat led in 1966 to a moratorium on timber harvest and road construction and a subsequent watershed rehabilitation effort throughout the watershed (Megahan et al. 1980). There are no major water diversions and no dams in the SFSR drainage or downstream to the Snake River.

Mass erosion began to occur in the SFSR during the 1950s following soil disturbances from logging and road construction (Kiefer et al. 1992). Major storm events in 1964 and 1965 resulted in landslides and catastrophic sedimentation from disturbed slopes into several tributaries and the mainstem. Sediment deposition declined significantly from 1966-75 and more slowly through the early 1980s (Platts et al. 1989, Bohn and Megahan 1991). While recent conditions are considerably improved from those in the mid-1960s, complete habitat recovery has not occurred. Johnson Creek was apparently unaffected by the catastrophic erosion documented for the SFSR mainstem, although sediment problems exist. Ortmann (1968) found significantly cleaner chinook spawning gravel in Johnson Creek compared to the Poverty Flat area in 1966. Rearing and over-wintering habitats were degraded by the catastrophic sedimentation in the South Fork Salmon River downstream from Poverty Flat and by sediment and pollutants from Stibnite Mine operations since the 1940s in the East Fork of the South Fork Salmon River downstream from Johnson Creek (Thurow 1987). Depending on how far downstream of the spawning area the juveniles from Johnson Creek reared and over-wintered, the SFSR mass erosion events could also have reduced winter survival beyond the levels extant in the early 1960s.

Summer water temperatures are suitable for rearing salmonids throughout the SFSR drainage. No historic inventory data are available regarding frequency of quality pools or temporal changes in the SFSR, however pools were known to be filled with sediment in the mid-1960s. Large pools suitable for resting by returning adult salmon are common in both SFSR index areas.

The South Fork Salmon River (SFSR) mainstem is managed for natural and hatchery summer chinook and wild steelhead (Kiefer et al. 1992). The McCall Hatchery program was developed in the late 1970s as mitigation for effects from hydropower development under the Lower Snake River Compensation Program. Snake River summer run fish were collected at Lower Granite and Little Goose dams for initial broodstock; since 1981, only fish returning to the SFSR have been used for hatchery broodstock. A weir, located 115 km upstream from the mouth, has intercepted adults for the hatchery since 1980; smolts are also stocked a short distance upstream of the weir. The Stolle Meadows spawning area, upstream from the weir, has been directly influenced by hatchery weir operations and releases of juvenile and adult hatchery fish. The Poverty Flat spawning area, located about 27 km downstream of the hatchery weir, has not been stocked with juvenile hatchery fish, and appears to be minimally affected by dropout of hatchery-origin spawners based on observations of few coded wire tagged fish in carcass samples (E. Bowles, IDFG, pers. comm.). This tentative conclusion can be tested beginning in 1996, at which time all returning hatchery chinook will be adipose-clipped. The Johnson Creek summer chinook population is maintained by natural spawning, although McCall hatchery fish have been reintroduced in the upper drainage above a barrier removal project.

Sport harvest on wild chinook has been closed since 1965 in the SFSR. SFSR summer chinook were previously harvested in sport fisheries in the tributaries, mainstem SFSR and in the Salmon River. Horner and Bjornn (1981) estimated that, on average, 22% of Idaho spring/summer chinook sport harvest occurred in the SFSR drainage from 1959 to 1964. Tribal harvest also occurred historically on SFSR chinook; since 1981 SFSR tribal harvests ranged from 0 to 95 wild and 0 to 207 hatchery fish (TAC 1996).

Imnaha

Index populations in the Imnaha basin include the mainstem-spawning population and a combined Big Sheep Creek and Lick Creek population (Figure 7). These populations include all significant spawning areas in the basin. The Imnaha River drains alpine zones, forest, and semi-arid rangelands through deeply incised valleys from elevations of 3,000 m in the Wallowa mountains to 300 m at the mouth (NPT et al. 1990). Granitic soils predominate in the upper basin and basaltic soils predominate in the lower basin. Vegetation consists of grasses and sage brush in the lower plateaus and valleys, and pines and firs at higher elevations. Precipitation ranges from averages of 150 cm/yr at high elevations to 35 cm at lower elevations. The basin is managed primarily by the U. S. Forest Service (71% of basin) and large areas are in the Eagle Cap Wilderness (9%) and Hells Canyon National Recreational Area (41%). Private ownership extends from the mouth of the Imnaha River upstream to Rkm 82.

Widespread overgrazing by cattle and sheep peaked before 1930 in eastern Oregon and since has declined to significantly lower levels (Wissmar et al. 1994). Cattle grazing remains the major land use activity on private lands in the Imnaha Basin and some fields are also planted in hay. Logging occurs in nonwilderness areas and approximately 20% of the basin contained saw lumber in 1960 (OWRB 1960). Road construction along the Imnaha during the winter of 1952-53 caused a large slide 24 km above Imnaha (Gunsolas et al. 1953). The slide apparently impeded but did not completely block salmon migration for at least 2 years. Mining activities have generally been limited to a few small low-grade copper deposits near river mouth and habitat has not been significantly degraded by mining. The only major irrigation withdrawal in the basin diverts water from lower Big Sheep Creek into the Wallowa Valley (NPT et al. 1990). Several dozen small water rights in the basin also divert water and most are in the Big and Little Sheep systems. Diversions upstream from the town of Imnaha reduce summer discharge by approximately half. No significant impoundments have been built in the Imnaha basin.

Wilderness areas in the headwaters result in high quality habitat for salmon in the Imnaha mainstem with only minor increases in sedimentation due to land use practices (NPT et al.

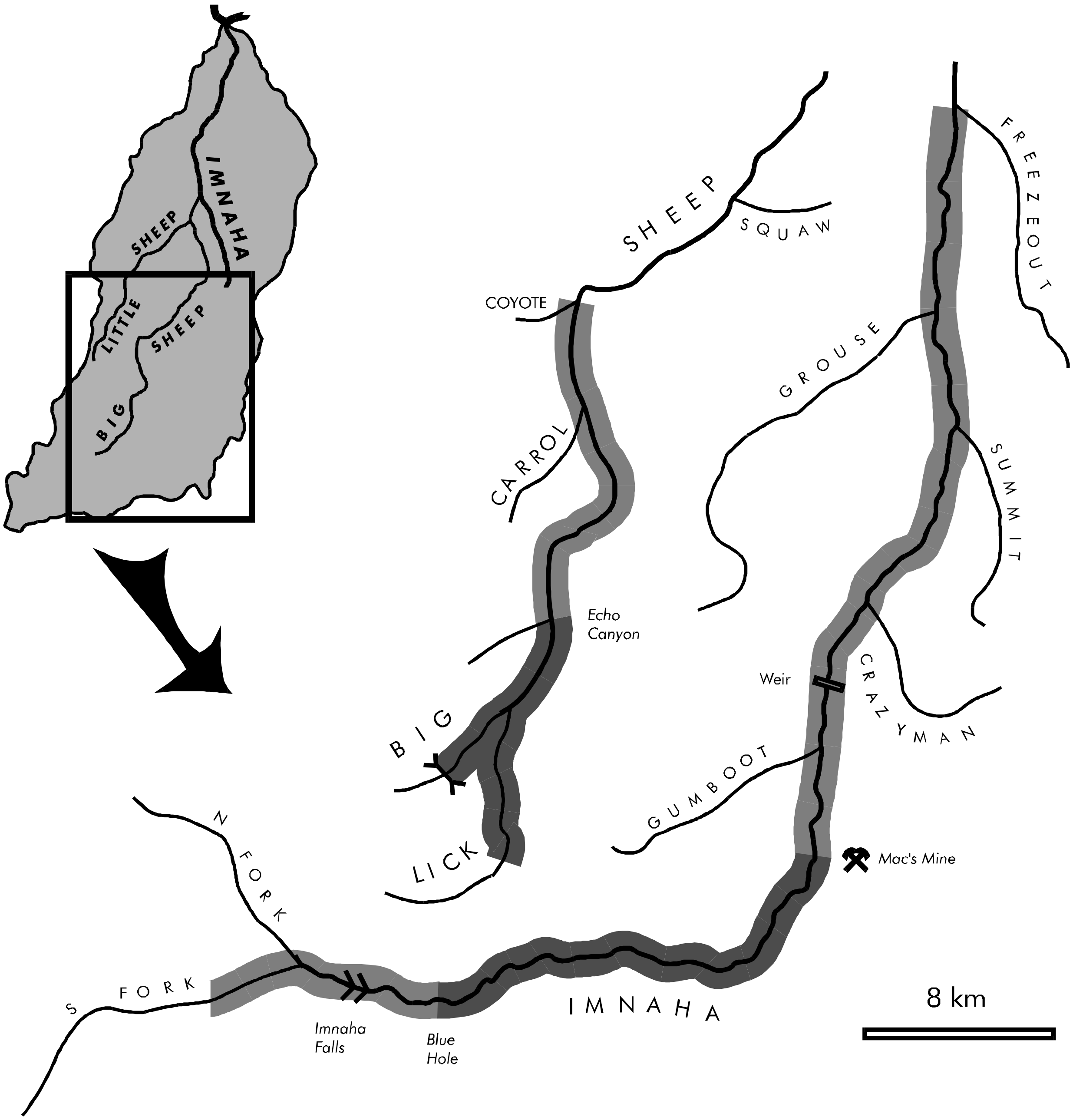

FIGURE 7. Spawning and index areas for the Imnaha River and Big Sheep/Lick Creek populations of spring/summer chinook salmon. Index areas are denoted in dark gray and other spawning areas used by this index are denoted in light gray.

1990). Cattle grazing has affected riparian vegetation and bank stability in some areas of the basin, especially in private lands along Big Sheep Creek, Little Sheep Creek, and the lower Imnaha River (NPT et al. 1990). Water temperature in the Imnaha mainstem averages from 35°F in winter to 61°F in summer and these temperatures are ideal for salmonids.

The Imnaha River is managed for wild and hatchery spring/summer chinook (NPT et al. 1990). Significant natural spawning by hatchery fish occurs in mainstem areas downstream from a weir at RKM 74 and also upstream from the weir where current management practices limit hatchery fish to <50% of the number passed (Olsen et al. 1994b). A broodstock collection and smolt acclimation facility was built on the mainstem Imnaha at Rkm 74 in 1982 (Olsen et al. 1994b). Broodstock was established from wild fish collected at the weir beginning in 1982 and broodstock currently include hatchery-origin and wild adults. Imnaha-stock fish are removed to Lookingglass Hatchery for rearing but are returned to the Imnaha facility for acclimation and release as smolts. The exceptions were in 1987 when Imnaha stock smolts were released at Lookingglass Hatchery because of disease concerns, 1990 when smolts were also released in Big Sheep Creek, and 1994 when presmolts were released in Big Sheep Creek, Little Sheep Creek, and the Imnaha River. Annual releases of smolts have ranged from 4,000 to 596,000 smolts from 1984-94 and have averaged 373,000 from 1990-94. Releases in 1984 and 1986 included Imnaha and Lookingglass Creek origin smolts. In 1966, jacks and adults collected at Hells Canyon Dam were outplanted in the basin (101 in the Imnaha River and 18 into Lick Creek). Hatchery fish collected at the Imnaha weir were also outplanted in Lick Creek in 1993.

The Imnaha basin sport fishery for spring chinook salmon was closed in 1974 and has remained closed since except for 1977 (Olson et al. 1994b). The Nez Perce and Confederated Umatilla Tribes historically harvested spring chinook in the Imnaha Basin. The Nez Perce Tribe closed the Snake River and all its tributaries to subsistence fishing in 1984 (Howell et al. 1985).

Grande Ronde

Catherine Creek, Lookingglass Creek, Lostine River, Minam River, upper mainstem Grande Ronde River, and Wenaha River populations were used as index areas for spring chinook salmon in the Grande Ronde subbasin (Figure 8). Bear Creek, Indian Creek, and the Wallowa River also contain limited spawning habitat for spring chinook (ODFW et al. 1990b, Olsen et al. 1994a). The Grande Ronde River arises in the Blue and Wallowa mountains at elevations up to 3,000 m and drains a variety of terrain types including alpine zones, forested plateaus, flat agricultural valleys, and semi-arid range land (ODFW et al. 1990b). The basin includes a variety of sedimentary, igneous, volcanic, and alluvial rock types which have been faulted, folded, and uplifted. Climate is semi-arid although higher elevations may receive 100-125 cm of precipitation per year, most of it as snow. Forested areas at mid to high elevations are dominated by ponderosa pine, grand fir, white fir, and Douglas fir. Vegetation in low to mid elevation areas is predominately of a steppe type dominated by perennial grasses. The U. S. Forest Service manages about 45% of the land in the Grande Ronde Basin (ODFW et al. 1990b). All or part of the Minam, Wenaha, Lostine, and lower Grande Ronde rivers and Joseph Creek were designated as Wild and Scenic Rivers in 1988. Most of the Minam drainage is in the Eagle Cap Wilderness which was established in 1940 and expanded in 1972. The Wenaha River is located in the Wenaha/Tucannon Wilderness Area which was established in 1978.

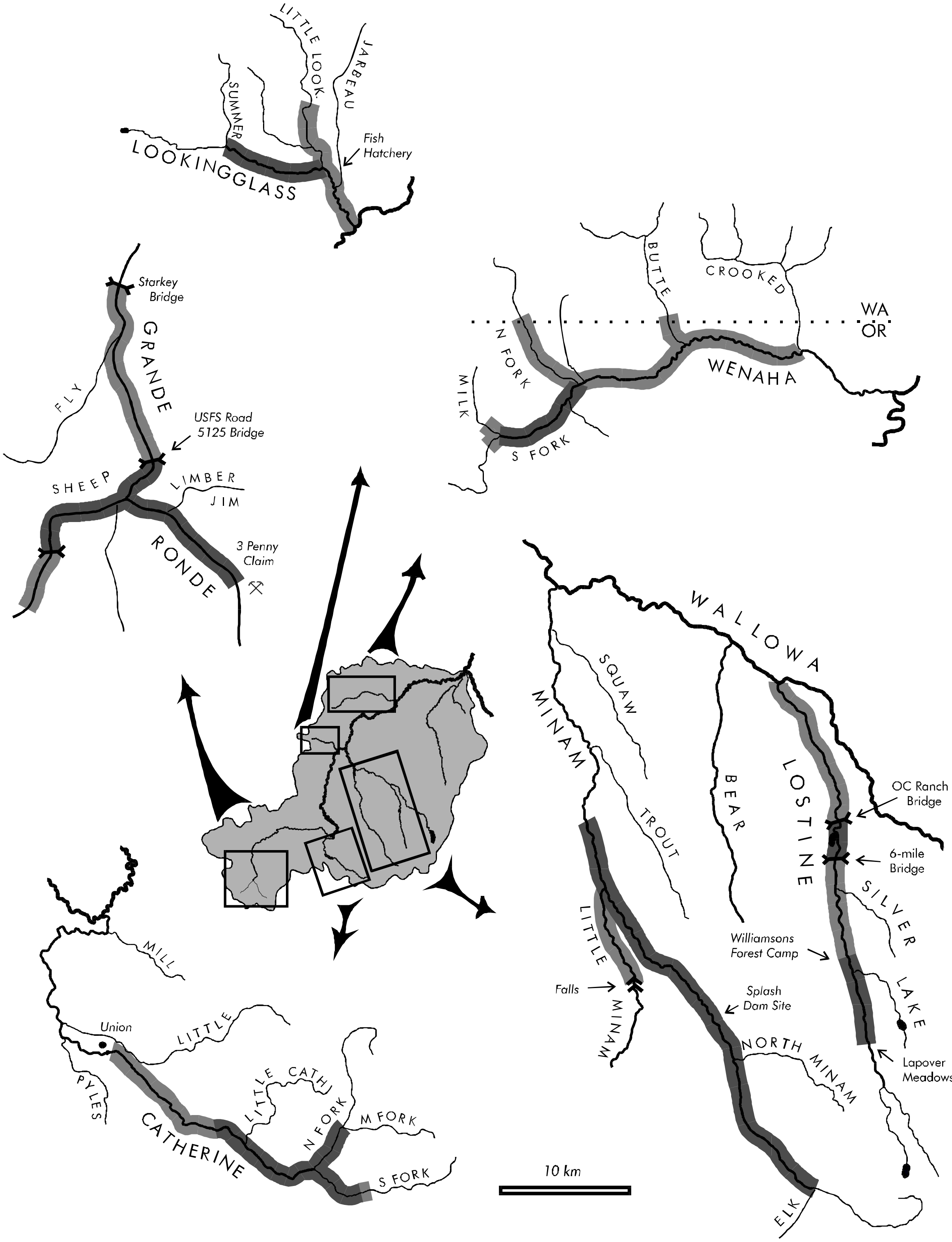

FIGURE 8. Spawning and index areas for the upper Grande Ronde River mainstem, Catherine Creek, Lookingglass Creek, Lostine River, Minam River, and Wenaha River populations of spring chinook salmon in the Grande Ronde River subbasin. Index areas are denoted in dark gray and other significant spawning areas are denoted in light gray.

Historic land use records indicate that domestic livestock grazing, splash dams and associated log drives, and mining have significantly impacted anadromous fish habitat and streamflows in the Grande Ronde basin prior to 1941 (Wissmar et al. 1994). Portions of the basin were already overgrazed by the 1880s. Grazing peaked before 1930 and by 1990, grazing in the Wallowa-Whitman National Forest had declined by almost 80% (McIntosh et al. 1994). Timber harvest and road construction in the Grande Ronde basin have increased substantially since the 1950s and currently dominate land use activities in non-wilderness portions of the upper basin (Wissmar et al. 1994). Significant logging activity in the Minam drainage began around 1900 and ended before 1940 (Donaldson and Schoning 1949). A splash dam near the upstream limit of good chinook spawning habitat around Rkm 50 was an obstacle to fish passage until and for some years after it was blasted out around 1940. Removal of the splash dam loosened large amounts of granite sand which scoured and filled the substrate "many miles" downstream and affected fish habitat quality at least until 1949 (Donaldson and Schoning 1949). Headwaters of many streams in the Grande Ronde basin were dredged extensively for gold from 1870 into the early 1900s and mining has significantly altered the river and its floodplain (McIntosh et al. 1994). The upper Grande Ronde was most severely affected by mining.

Irrigated agriculture dominates land uses in the Wallowa and Grande Ronde valleys. Numerous irrigation or water supply diversions were barriers to salmon passage in Catherine Creek and the Lostine River until at least the 1960's. No significant irrigation diversions currently exist in spawning or rearing areas of the Minam and Wenaha rivers or in migration corridors of the lower Wallowa and Grande Ronde rivers. Historically, 12 small to medium pumps diverted water from the lower Grande Ronde River but only five remain active and all are screened. No large impoundments have been built in the Grande Ronde mainstem or major tributaries.

The wilderness designations of the upper Minam River and Wenaha drainages preclude damaging land uses and both contain high quality spawning and rearing habitat. Stream temperatures in the Minam and Wenaha rivers are optimum for salmonids, riparian habitat is healthy, and substrates have largely recovered from historic sedimentation problems. Warm summer temperatures may constrain the availability of rearing habitat in portions of the Wallowa River, Grande Ronde River, and Catherine Creek.

Significant numbers of hatchery fish have been recovered from spawning grounds throughout the Grande Ronde basin since 1986. In some years, fish released as smolts from Lookingglass hatchery have contributed more than half of the natural spawners. Lookingglass hatchery was established in 1980 on Lookingglass Creek downstream of the Minam River (ODFW et al. 1990b, Olsen et al. 1994a). Wallowa Hatchery is also operated by ODFW upstream from the Minam River but releases steelhead and rainbow trout. Releases of spring chinook from Lookingglass Hatchery began in 1980 using Rapid River stock. In 1982, Rapid River stock were replaced with Carson stock because of disease concerns. A Lookingglass Creek stock was subsequently developed using returns to the hatchery. Carson and Lookingglass Creek stocks were no longer released after 1988. Rapid River stock were again released from 1988 to present. Smolt releases into the Grande Ronde system from 1981 to 1995 ranged from 430,000 to 1,760,000 and averaged 935,000. Presmolts were also released in 1983 (980,000), 1985 (130,000), and 1986 (100,000). Current releases are made directly from Lookingglass Hatchery but between 1980 and 1988, releases were periodically made in Catherine and Big Canyon creeks and in the upper Grande Ronde River. Adults have been outplanted in Catherine Creek, the

Wallowa River, and the upper Grande Ronde River in 1987-88. No hatchery-reared juveniles or adults have been released nor have adults been collected for hatchery broodstock from the Lostine, Minam, or Wenaha rivers.

Sport fisheries for spring chinook salmon in the Grande Ronde basin have been closed since 1978 in Oregon and 1977 in Washington (ODFW et al. 1990a, 1990b). The Nez Perce and Confederated Umatilla Tribes historically harvested spring chinook from usual and accustomed sites throughout the Grande Ronde basin and the maximum recorded harvest was 300 in 1968 (West 1968). The Umatilla Tribes closed the Grande Ronde to subsistence fishing in 1982 and 1983, and the Nez Perce Tribe closed the Snake River and all its tributaries to subsistence fishing in 1984 (Howell et al. 1985).

Methow

Spring chinook spawn within most of the upper reaches of the Methow (Figure 9): the 11.4 km below Eureka Creek in the Lost River; the 12 km below the falls in Early Winters Creek; the 51.7 km below the falls in the Chewuch (a.k.a., Chewuck or Chewack) River, including the lower 8.3 km of Lake Creek; the 42 km below North Creek in the Twisp; and, the mainstem Methow River from Robinson Creek (Rkm 120) down to the town of Carlton (Rkm 44). Potential spawning areas include the lower 2.2 km of Wolf Creek, and the lower portions of Gold Creek (Kohn 1987). The lower couple of kilometers in the Chewuch River, Lake Creek, and Twisp River are not good spawning habitat, though occasional spawning occurs there. The area above Eureka Creek in the Lost River, and the area above the first kilometer of Early Winters Creek, rarely have spawners. The 40 km of index areas were first identified by Meekin (1963), and French and Wahle (1965): Lost River (Rkm 0.0 to 0.6, and 0.6 to 6.3); Early Winters Creek (Rkm 0.0 to 3.1); upper Methow River (Rkm 96.1 to 105.2); Chewuch (Rkm 21.9 to 32.8); and Twisp River (Rkm 20.4 to 32.8). Additional mainstem Methow River sections from Weeman Bridge (Rkm 96.1) down to Benson Creek (Rkm 51.5), are no longer used as index areas, but are surveyed (Kohn 1987, Scribner et al. 1993).

The Methow subbasin drains an area of approximately 4,600 square kilometers from an elevation of over 1,800 meters, just east of Harts Pass in the North Cascades, down to 236 meters where the Methow and Columbia rivers meet at Pateros, WA (Rkm 838.3). The upper portion of the Methow subbasin is heavily forested, progressing from a subalpine fir to a Douglas fir, and then to a ponderosa pine vegetation zone. Lodgepole pine forests occur where climax vegetation zones have been damaged by fire. In this North Cascades ecoregion (Omernik 1995), the climate is both maritime and continental. Snow falls up to 13 meters, and average annual precipitation ranges from 200 – 250 cm/year. Winter temperatures are freezing, and can get down to minus 25 degrees Fahrenheit. Here the river flows over granite and gneiss in the Skagit metamorphic suite, and then through a glacial U-cut valley composed of the Methow graben--sandstone formations between the towns of Mazama and Twisp (Alt and Hyndman 1984). Alluvial fan and alluvial plain deposits, between the town of Mazama and the lower reaches of Lost River, are so deep that late summer flows are often subsurface, preventing or delaying adult passage, and stranding juvenile fish (WDW et al. 1990a). The lower Methow

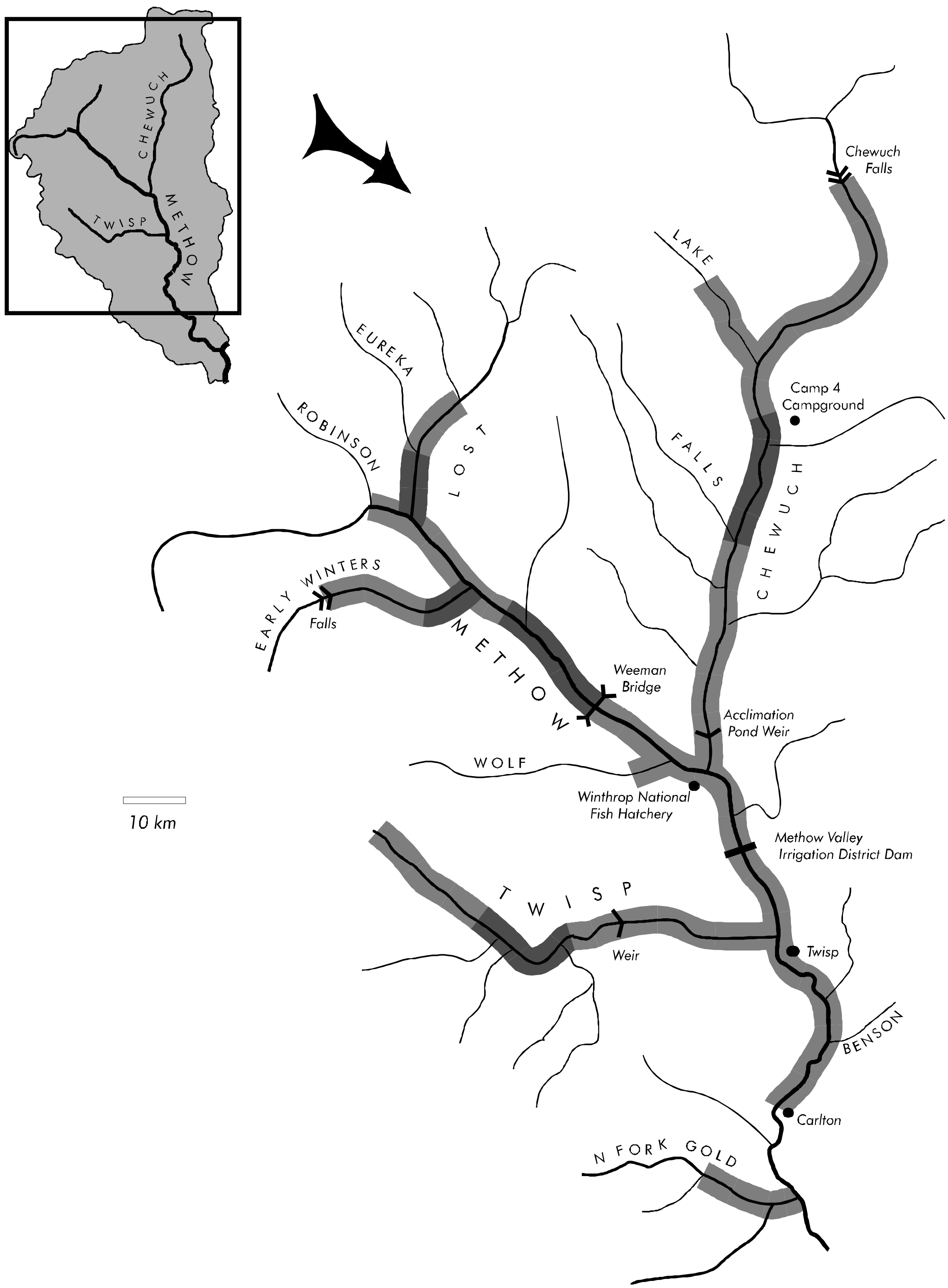

FIGURE 9. Spawning and index areas for spring chinook salmon in the Methow River subbasin. Index areas are denoted in dark gray and other marginal spawning areas are denoted in light gray.

Valley is part of the Columbia Plateau ecoregion (Omernik 1995), having a continental climate. Snow fall ranges between 25 and 50 cm/year, and average annual precipitation drops to 25 cm/year. The ponderosa pine zone gives way to the grass and shrub vegetation zone. Below the Methow graben (below the town of Twisp), the geology shifts to a mixture of gneiss, schist, and granite (Alt and Hyndman 1984). While half of this lower portion is classified as a confined U-shaped alluvial valley bottom type, orchards, hay fields and small ranches occupy the less confined areas (Hillman and Ross 1992). Mullan et al. (1992) noted that the privately-owned lands are mostly in this lower portion(while 80% of the Methow River basin is in public lands managed by the Forest Service). The flow in this watershed is driven by winter snowpack. Approximately 50 to 70% of the annual flow occurs in May and June, though short-term peak flows can be created by summer thundershowers or winter rain-on-snow events (WDF 1990).

Grazing by sheep and cattle severely affected habitat conditions in the Methow basin before 1930 (McIntosh et al. 1994). Significant timber harvest and road building began in the late 1950s and increased since the 1970s (McIntosh et al. 1994). Numerous mining claims have been filed in this region since 1870, but production has been limited, and effects temporary (Mullan et al. 1992). Recreational gold panning still goes on in the Methow. A hydroelectric dam near the mouth of the Methow completely blocked upstream migration of anadromous salmonids from 1912 to the 1930s (Mullan et al. 1992, Bryant and Parkhurst 1950). The majority of irrigation withdrawals occur below the town of Leavenworth. The largest diversion dam (operated by the Methow Valley Irrigation District) is located at Rkm 44.8, between the towns of Twisp and Carlton. The majority of irrigation withdrawals occur in the lower portion of the subbasin (the migratory corridor for the spring chinook).

Fish habitat conditions in the Methow basin appear to be recovering from past land management practices based on significant increases since 1934-42 in the frequency of large pools during resurveys in 1990-92 (McIntosh et al. 1994). Riparian zones are still wide in the upper reaches; however, the projected development of recreational facilities, and seasonal residences pose a threat. The lower Methow riparian zones are more fragile and damaged due to livestock grazing, farming practices, and roads constructed adjacent to the river. Nonetheless, water quality in the lower Methow River remains high, with an AA rating from the Washington Department of Ecology (Hubble and Sexauer 1994). Canals, ditches and surface irrigation systems have given way to closed-pipe conveyances of water with sprinkler application (WDW et al. 1990a).

The Washington Department of Fisheries (now Fish and Wildlife) built the first hatchery (primarily for coho salmon production) on the Methow River in 1899 at the confluence of the Twisp and Methow rivers (Craig and Suomela 1941). This facility operated until a new hatchery was built near the confluence of the Methow and Columbia rivers in 1915 as a result of the Washington Water Power dam having no fish ladder. While some Methow chinook eggs were taken between 1908 and 1916, the 1.5 million eggs received in 1917, and the 2.5 million eggs received from 1926-31, were most likely from lower Columbia River hatcheries (Craig and Suomela 1941). The Winthrop National Fish Hatchery was completed in 1941, at Rkm 82 in the Methow River, as part of the Grand Coulee Fish Maintenance Project (GCFMP). Spring chinook reared at the Leavenworth NFH (Wenatchee subbasin) were released in the Methow in the fall of 1941 and 1943. From the first Winthrop NFH release in 1943, until 1963, the releases were composed of either parr or fry, reared from eggs taken from adults collected at Rock Island Dam, the Entiat River or the Methow River. Winthrop National Fish Hatchery resumed spring chinook releases in 1975. For the first decade, eggs were mostly brought in from outside sources including significant contribution from the Little White Salmon NFH on the lower Columbia River, and Carson NFH on the Wind River (Peven 1992). Since 1977, hatchery fish have contributed up to an estimated 20% of the naturally spawning population. Starting in 1992, brood stock for the natural supplementation program was collected at weirs in the Twisp and Chewuch rivers, and at the outfall of the Methow Valley Spring Chinook Hatchery (a Washington Department of Fish and Wildlife operated mitigation facility located near the Winthrop NFH). The progeny of these fish are reared at the hatchery and released from acclimation ponds near their collection site. The Methow Basin Spring Chinook Salmon Supplementation Plan (MBSCSP) is derived from compensations agreed to by Douglas County PUD in the Wells Dam Settlement Agreement, and from spring chinook compensations transferred from Chelan County PUD's Rock Island Settlement Agreement (WDW et al. 1990a, Hubble and Sexauer 1994).

Since at least 1960, there has been no harvest of spring chinook in the Methow subbasin. According to Craig and Hacker (1940), a tribal fishery was conducted at the mouth of the Methow River historically, but it has not existed for decades. It is assumed that early settlers also made use of the resources. Mullan et al. (1992) estimated that the aboriginal fishery harvested about 228,125 pounds of salmon annually. This was based on consumption rates and a maximum population estimate of 500 Methow Indians during the mid-19th century. Through further deduction, they concluded that 45 percent of the catch by weight was chinook, which would be about 8,066 fish based on average weight (no distinction was made between spring and late-run chinook). Terminal harvest rate was estimated to be in the range of 20-50 percent.

Both natural and hatchery stocks are considered to be descended from fish trapped at Rock Island Dam between 1939-1943 as part of the GCFMP, and from lower Columbia River stocks that were introduced in the last 17 years (Peven 1992). In fact, a truly native Methow fish has probably not returned since 1916, because of the Washington Water Power dam mentioned above. Marshall et al. (1995) group the natural spring chinook stocks from the Methow, Entiat, and Wenatchee subbasins into the Upper Columbia Spring Chinook Genetic Diversity Unit (GDU). This means that the Washington Department of Fish and Wildlife recognize these stocks as being genetically similar, and as a group genetically distinct from other such groups. It also means that these stocks exhibit similar life histories, and occupy ecologically, geographically, and geologically similar habitats. None-the-less, the natural supplementation program in the Methow has cautiously maintained a separation between fish collected in the Chewuch, Twisp, and mainstem Methow. Marshall et al. (1995) do suggest that hatchery influences are probably decreased in the tributaries farthest from the facilities, such as the Twisp River. A small number of spring chinook spawn in the uppermost spawning areas of late-run chinook. Spring chinook are reproductively isolated from late-run chinook except perhaps in years with large run sizes where overlap is more likely from individuals on the fringes in timing and location. (Marshall et al. 1995). Late-run is a term used to describe chinook that pass Rock Island Dam after June 23rd (Peven and Mosey 1996). Mullan (1987) concluded that a distinction between a summer and a fall run was not warranted for the upper Columbia River. Late-run chinook are also referred to as summer/fall, or simply summer chinook.

Entiat

Most natural spawning by spring chinook in the Entiat River occurs in the mainstem between Rkms 30 and 45 (Figure 10). The consistent index area is from Fox Creek Campground (Rkm 45.1) down to Ski Hill/Dill Creek (Rkm 33.6). While spring chinook may be found up to Silver Falls at Rkm 49.6 (French and Wahle 1965), many consider the box canyon 3 km below there to be the end of the road for spawners. Consistent with this later opinion, recent spawning surveys have begun at Lake Creek (Rkm 46.2). No spring chinook spawning takes place in the North Fork (Rkm 52.8) since this flows into the Entiat River above Silver Falls. French and Wahle (1965) stated that the lower extent of spawning is just below Stormy Creek (Rkm 29.4). However, the discovery of two redds in the Mad River (enters the Entiat at Rkm 16.8) during the 1995 spawning survey spot check, indicates that spawn may occur lower in the subbasin then thought. The Entiat Subbasin was formed by a glacier that extended down the east side of the Cascade Range, from Mount Maude to Potato Creek (Rkm 24.3). Valley configuration above the moraine is U-shaped, while downstream of the moraine, the main valley and tributaries are typical stream-incised V-shape. This transition in valley type has been use here to define the lower extent of spawning. Adding on about half a kilometer of spawning habitat in the Mad River, the total length of spawning habitat is 23 km.

The watershed covers an area of 1,073 km^2, ranging from an elevation of 2,700 m down to 200 m where the Entiat River flows into the Columbia River at the town of Entiat (Rkm 774). Geological uplift, glaciation and volcanic activity have all combined to create a complex geological structure. The subbasin is primarily composed of metamorphic schist and gneiss, intrusive granodiorite, and quartz diorite (Washington Department of Fisheries et al. 1990a, Alt and Hyndman 1984). Much of the watershed is covered by volcanic ash and pumice, which originated from Glacier Peak. Generally, the soils are highly erosive, especially on steep slopes and after disturbance. Most of the subbasin falls within the North Cascade Ecoregion. Annual precipitation in the forested headwaters is 178 cm, while precipitation drops to less than 25 cm in the semi-arid grasslands of the lower portion that falls within the Columbia Plateau Ecoregion. The majority of precipitation falls as snow, though summer thunderstorms accompanied by intense rain are common. Typical of streams on the east slopes of the Cascade Mountains, the Entiat River experiences high flows in the spring and early summer during snow melt, then very low flows during late summer and early fall. The Entiat Subbasin has large areas where the U. S. Forest Service and private timber companies form a checkerboard pattern of ownership. Approximately 87 percent of the watershed is used for timber production (Washington Department of Fisheries et al. 1992). Livestock grazing is common throughout the forested areas, though only 20 percent of the basin is suitable for grazing). In the lower 16 km of the subbasin, a narrow band of orchards line the riverbanks. Above there, most of the bottomland is in pastures. Less than one percent of the watershed is farmed (Mullan et al. 1992). Recreational homes dot the riverbanks in the upper watershed. Despite all the various private land uses, only 13 percent of land is in private ownership; 84 percent is federal lands, and 3 percent state lands (Washington Department of Fisheries et al. 1990a).

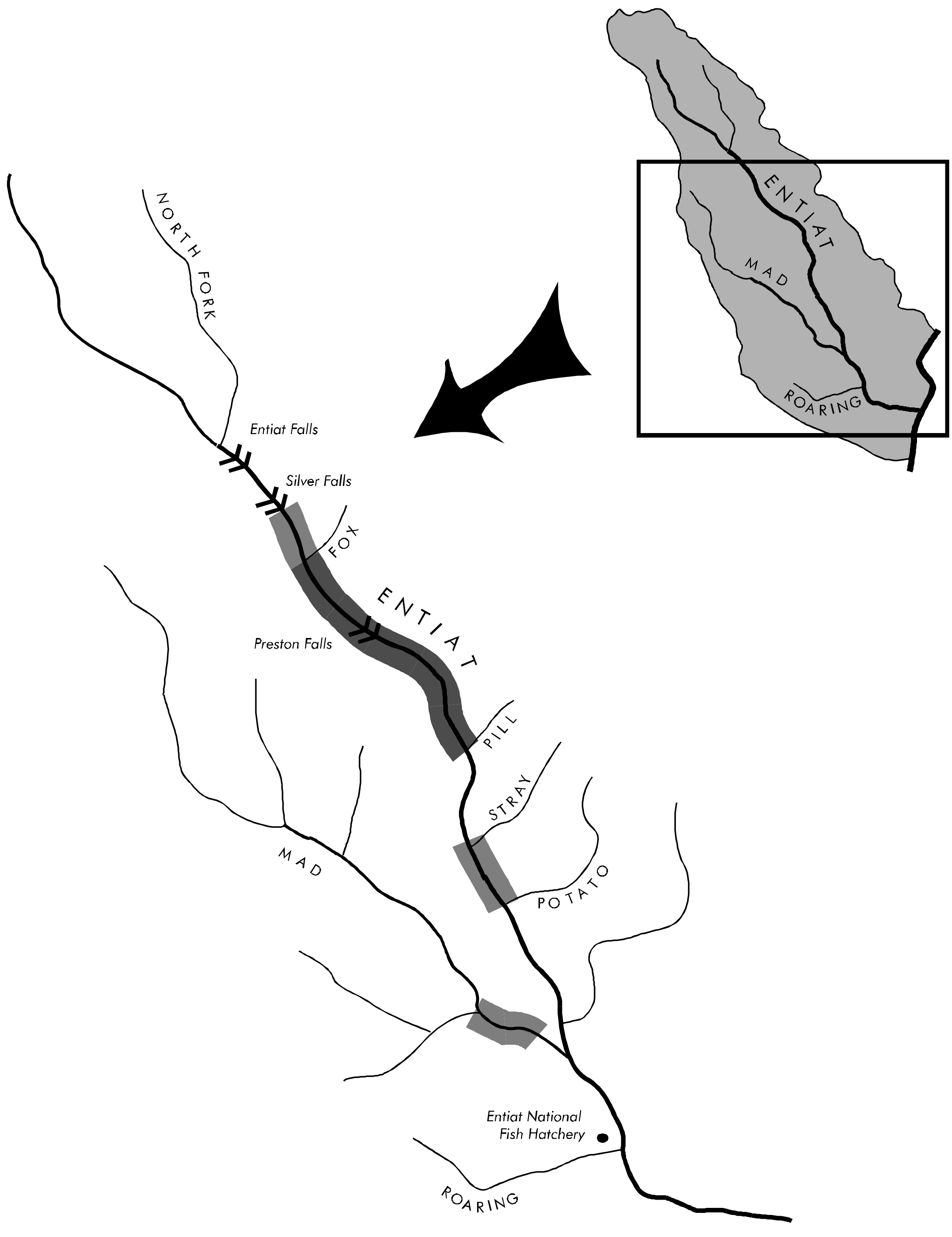

FIGURE 10. Spawning and index areas for spring chinook salmon in the Entiat River subbasin. Index areas are denoted in dark gray and other marginal spawning areas are denoted in light gray.

In 1898, a dam ,with a crude fish ladder, was built at a sawmill located one or two kilometers above the mouth of the river. Shortly there after, another dam with no fish ladder was constructed, completely cutting off salmon from the spawning grounds for several years (Craig and Suomela 1941). Numerous mining claims have been filed in this region since 1870, but production has been limited, and effects temporary (Mullan et al. 1992). Natural production of spring chinook in the Entiat basin has been reduced by water diversion (Hymer et al. 1992). Low-velocity rearing habitats have been lost through shoreline armoring and fill work done to protect roads, dwellings, and orchards Washington Department of Fisheries et al. 1990a).

The riparian area on national forest land is generally timbered except where the overstory has been removed by fire. Catastrophic wildfires have had a great impact on the watershed. Massive fires occurred in the 1880s, early 1900s, 1970, 1976, and 1988. The 1970 and 1976 fires were followed by major flood events that transported large amounts of sediment into the Entiat channel. A 44 percent mean annual increase in total water yield, accompanied with abnormal high and low flows, followed these fire events. Remedial channel modifications, taken in response to fire and storm events, have permanently altered habitat in some reaches. Erosion and stream channel instability increased significantly between the North Fork and Mad rivers. Riparian areas along the lower reaches of the Entiat River have been modified to accommodate dwellings and agricultural development (Washington Department of Fisheries et al. 1990a).

Entiat National Fish Hatchery at Rkm 10 has been releasing spring chinook since 1942 (Hymer et al. 1992). Early releases were from broodstock intercepted at Rock Island Dam as part of the Grand Coulee Fish Maintenance Plan (Washington Department of Fisheries et al. 1990a). A data gap occurs in the hatchery records for brood years 1957 through 1967 (personal communication, U. S. Fish and Wildlife Mid-Columbia FRO staff). Spring chinook production resumed at the hatchery in 1970s with release of Klickitat Hatchery fish in 1972 and 1974. Entiat stock was released in 1975. In subsequent years, collection shortfalls were supplemented with various Carson (Wind) or Cowlitz based stocks. Most releases have been smolts at about 19 fish to the pound (Hymer et al. 1992). Adult collection records from 1975 until 1979 are not clear as to the disposition of fish returning to the hatchery rack.

Terminal harvest in the Entiat has been minimal. In 1986 and 1987, limited sport fisheries were held near the Entiat NFH, with sport fishers harvesting 10 and 28 fish respectively. None of these fish are likely to be wild due to the timing and location of the fishery. Mullan et al. (1992) estimated historical tribal subbasin harvest to be 31,938 pounds annually. This estimate was based on an assumption that 140 Entiat Indians lived in the region during the 19th century, and that at least half of the salmon they consumed came from outside the subbasin. With chinook being the dominant species in the watershed, they assumed that spring chinook accounted for half of the catch weight. This would correspond to 1.141 fish. No tribal fisheries occur in the Entiat River today.

Both natural and hatchery stocks are considered to be descended from fish trapped at Rock Island Dam between 1939-1943 as part of the GCFMP, and from lower Columbia River stocks that were introduced in the last 23 years. The total blockage of runs to the Entiat, by sawmill dams built in the late 19th century, most likely exterminated indigenous stocks (Craig and Suomela 1941, Mullan et al. 1992). Upstream passage was either blocked or significantly limited in all upper Columbia tributaries around the turn of the century. This would suggest that an even earlier mixing of stocks might have occurred. Marshall et al. (1995) group the natural spring chinook stocks from the Methow, Entiat, and Wenatchee subbasins into the Upper Columbia Spring Chinook Genetic Diversity Unit (GDU). Interviews with people, who had lived in the Entiat watershed before this century, indicate that there has never been a late-run component to the chinook population, only a spring-run (Craig and Suomela 1941).

Wenatchee

Presently, spring chinook populations sustained by natural spawning occur in all the major tributaries and in the mainstem of the Wenatchee River upstream from Tumwater Canyon (Figure 11). Specifically, the limits to spawning are: White River (from mouth to White River Falls at Rkm 22.9); Little Wenatchee River (from about Rkm 5.0, below Lost Creek, to Little Wenatchee Falls at Rkm 12.5); Nason Creek (from mouth to Rkm 25.3, below Gainer Falls); Chiwawa River (from mouth to Phelps Creek at Rkm 48.3); and, in the upper Wenatchee mainstem (from Chiwaukum Creek at Rkm 57.4 to Lake Wenatchee at Rkm 86.7). Occasionally, spring chinook spawning is reported in Peshastin Creek, between Mill and Ruby creeks (Rkm 7.7 to 15.5). The spring chinook spawning in Icicle River (Creek) include fish returning to the Leavenworth National Fish Hatchery (NFH), and the population is probably sustained primarily by the hatchery program (Peven and Mosey 1996, Hymer et al. 1992). Anadromous fish passage is blocked at Rkm 4.5, by the hatchery barrier dam. Meekin (1963), and French and Wahle (1965), established the index areas in the most heavily spawned stream reaches (Figure 11): Chiwawa River (Rkm 30.9 to 43.2); upper Nason Creek (Rkm 13.3 to 25.3); White River (Rkm 10.3 to 22.9); the Little Wenatchee River (Rkm 4.3 to 11.4); Icicle River (Rkm 0.0 to 4.5); and, the upper Wenatchee River mainstem (Rkm 57.0 to 86.7).

The Wenatchee River and its tributaries drain an area of 3,400 km^2 through deeply incised valleys of the east slope of the Cascade Range (Mullan et al. 1992, WDF et al. 1990b). The watershed originates at elevations exceeding 2700 m in the sub-alpine regions within the Alpine Lakes and Glacier Peak wilderness areas. The 26.4 km long Little Wenatchee River, and the 42.7 km long White River flow into Lake Wenatchee (at Rkm 93.8). This ultra-oligotrophic lake is about 989 ha in size, with an average depth of 55 m (Fast 1988). Unlike the other tributaries in the Wenatchee, Entiat, and Methow subbasins, the White River receives more of its water from glacial runoff rather than rain or snowpack (Marshall et al. 1995). From Lake Wenatchee's outlet (Rkm 86.7), the river is joined by Nason Creek, Chiwawa River, and Chiwaukum Creek, before it descends rapidly through Tumwater Canyon (hydraulic gradient 0.9%) to the town of Leavenworth, where Icicle Creek joins the mainstem (Rkm 41). Vegetation is mostly dense mixed forest dominated by Douglas Fir in this wet-cold region, which receives nearly 230 cm of precipitation annually. Snow accumulations exceed 9 m (WDF et al. 1990b). This mountainous region, west of the Leavenworth fault is primarily composed of hard and durable granite gneiss deposits of the Mount Stuart batholith (Alt and Hyndman 1984). The river continues southeastward through long sections of runs separated by low-gradient riffles with a hydraulic slope of approximately 0.3%. Three smaller tributaries join in this section: Chumstick Creek, Peshastin Creek, and Mission Creek. The mixed forest of the upper Wenatchee merges into the dry forest of the eastern foothills, where the ponderosa pine is the predominate species. As air masses move east toward the Columbia Basin, moisture decreases,

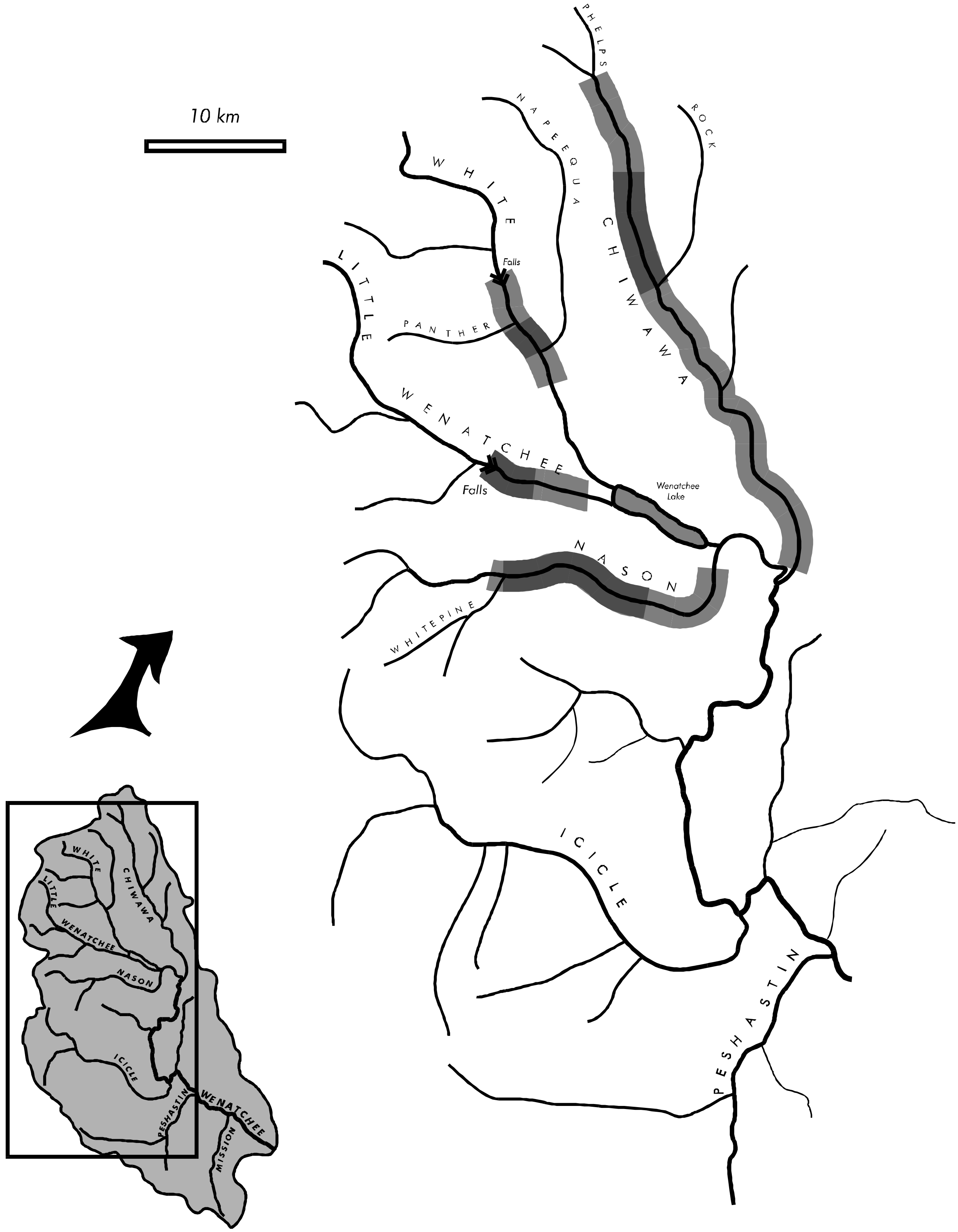

FIGURE 11. Spawning and index areas for spring chinook salmon in the Wenatchee River subbasin. Index areas are denoted in dark gray and other significant spawning areas are denoted in light gray.

resulting in arid conditions within the lowermost region of the watershed (less than 22 cm of precipitation annually). Maximum summer temperatures average 35 to 43 °C. Violent summer thunderstorms occur periodically, and can result in flash flood conditions on local watersheds. Natural vegetation shifts to sagebrush, bitter brush and grasses in this lower section (WDF et al. 1990b). The geological formations also change. East of the Leavenworth fault, lies the Chiwaukum graben. The graben consists mostly of the Chumstick formation of young very pale sandstone. Peshastin Creek crosses over the Leavenworth fault. The upper end of the creek flows through the sedimentary deposits of the Swauk formation (mostly brown fossilized sandstone, pebble conglomerate, and shale) and the Ingalls metamorphic complex (large deposits of serpentinite) formed along the south edge of the Mt. Stuart batholith (Alt and Hyndman 1984).

Approximately 77% of the Wenatchee land base are federally owned with the U. S. Forest Service by far the largest landowner (WDF et al. 1990b). Wilderness or roadless designations currently regulate land use on 65% of the Wenatchee National Forest (McIntosh et al. 1994). Of the remaining land, approximately 22% are privately held and 1% is state owned. Most of the private land is located in the lower reaches along the shoreline. Some of this land is urban developed, but most is in agricultural use. The City of Wenatchee proclaims itself the Apple Capital of the World. Orchards and processing plants blanket the watershed up to the town of Leavenworth. Upstream from the mouth of Tumwater Canyon, homes and other cultural development (camps, retreats, etc.) dot the shoreline (WDF et al. 1990b).

Grazing, logging, mining, hydroelectric projects, and irrigation diversions have all contributed to habitat degradation in the basin. Grazing by sheep and cattle severely affected habitat conditions before 1930 (McIntosh et al. 1994), especially in the high country (Mullan et al. 1992). There is little or no grazing of livestock today. Significant timber harvest and road building began in the late 1950s and has increased since the 1970s (McIntosh et al. 1994). A number of fires have burned portions of the watershed periodically, but the U. S. Forest Service has successfully pursued erosion abatement programs through reseeding (WDF et al. 1990b). Mining impacts are perhaps most evident in Peshastin Creek, where placer gold mining occurred from 1860 to 1940 (Mullan et al. 1992). The area was known for rich pockets of uncommonly large nuggets, and to this day weekend prospectors occasionally still find such nuggets. Early this century, several underground mines worked gold quartz veins, and the town of Blewett had a large stamp mill (Alt and Hyndman 1984).

In 1904 and/or 1905, the Lumber Company Dam was built at Leavenworth. Runs to the upper basin were weakened, as some salmon were not able to make it over this structure (Craig and Suomela 1941). Lumber Company Dam was likely removed early this century, but the actual year is not recorded. A small hydro project on Phelps Creek (near the upper boundary of spring chinook spawning in the Chiwawa River) has been providing electricity to small isolated camp/organization sites for over 30 years (WDF et al. 1990b). On the Wenatchee system there are three major diversion dams—Dryden, Icicle, and Tumwater. The 4.6 m high Tumwater Dam, located in Tumwater Canyon, was originally designed for hydroelectric purposes, but is no longer in operation although the structure remains. Dryden dam, the largest diversion in the watershed, is a 2.4 m high structure located in the lower Wenatchee mainstem (Rkm 27). Like Tumwater Dam, Dryden Dam was once used for power generation as well as irrigation withdrawal (Craig and Suomela 1941). It appears that the building of Dryden and Tumwater power dams in 1908, accelerated the decline of upper Wenatchee salmon runs, which all ready were impacted by the sawmill dam built a few years earlier at Leavenworth. Coho salmon disappeared, and late-run chinook declined (Craig and Suomela 1941). Dryden and Tumwater dams received new fish ladders in 1986 and 1987 (Fast 1988). Between Rkm 4.5 and 5.9, Icicle River divides into two channels—the original channel once used to hold adult salmon for the hatchery, and a diversion canal that provided the head to regulate flow in the other channel. In addition to these permanent diversion structures, numerous gravel diversion structures are seasonally maintained throughout the subbasin. Some snow lakes are used for late season flow enhancement on the Icicle River (WDF et al. 1990b). Irrigation withdrawals coincide with the natural low flow period of late summer-early fall. During these times, water temperatures below Leavenworth can exceed 21 °C. Tissue and sediment samples in 1984, by the Washington Department of Ecology, show a significant presence of arsenic, zinc, and E-DDT in the lower river (WDF et al. 1990b).

In 1899, the State of Washington built the first hatchery near the Chiwaukum railroad station just above Tumwater Canyon. The Chiwaukum Hatchery was closed in 1904, presumably due to the harsh and isolated conditions at the site, and due to an inability to secure a desirable broodstock. It was apparently reopened during the early 1930s since Washington Fish Commission annual reports show 2 million chinook eggs frozen/lost at Chiwaukum Hatchery in 1932. Records are not clear as to what species were actually taken, though the intent was to produce spring chinook and summer steelhead (Craig and Suomela 1941, Mullan et al. 1992, Peven 1992). Another hatchery was built below the canyon in the town of Leavenworth from 1913-1931. Apparently significant numbers of fish were not secured at this site, as many eggs were brought in from outside sources. Chinook eggs from Oregon's Willamette River were undoubtedly spring-run. However, shipments from the Little White Salmon River by the U. S. Bureau of Fisheries, and those made by other Washington hatcheries on the lower Columbia, could have supplied only extremely late fall running chinook (Craig and Suomela 1941, Mullan et al. 1992, Peven 1992).

Leavenworth National Fish Hatchery was built between 1938 and 1940, at Rkm 4.5 on the Icicle River. It served as the central hatchery facility for the Grand Coulee Fish Maintenance Project (GCFMP). During construction and the initial two years of operation of Grand Coulee Dam (1939 – 1943), all adult salmon were intercepted at Rock Island Dam (Fish and Hanavan 1948). Fish trapped for the hatchery program were spawned at the Leavenworth station, and a portion of the eggs was transferred to the substations in the Entiat and Methow rivers. All spring chinook trapped at Rock Island Dam but not used for artificial propagation, were relocated to Nason Creek in the upper Wenatchee Subbasin (Peven 1992, Fish and Hanavan 1948). Parr or fry (of Rock Island Dam origin) were released into the Icicle River from 1941-1944. The 1942 hatchery release into the Icicle River also included 239,400 parr originating from the McKenzie River (Willamette Subbasin). The Chiwawa River, Nason Creek, and Wenatchee River each received a single plant of spring chinook fingerlings in 1944 (Mullan 1987). No spring chinook were released from Leavenworth NFH during 1945-47. There were 804,300 fry of Icicle River origin released in 1948. For the next two decades, Leavenworth NFH did not produce spring chinook. Then in 1967, the hatchery released 251,000 smolt (of Spring Creek NFH origin) into the Icicle River. In the following year, 86,000 smolts of Eagle Creek NFH origin were released. Commencing in 1969, releases were made mostly from broodstock originating from outside the subbasin. Most eggs were obtained from Carson NFH (Wind River) with some being brought in from the Little White Salmon NFH, and Washington State's Cowlitz Salmon Hatchery. For the past fifteen years, the hatchery has been able to provide its own broodstock.. In addition to smolt releases into the Icicle River, a few fry plants were also made in Peshastin Creek in the late 1980s. (Washington Department of Fisheries 1990b, Peven 1992, personal communication with USFWS FRO Mid-Columbia personnel).

In order to obtain a license from the Federal Energy Regulatory Commission (FERC) to operate Rock Island Dam, Chelan County Public Utility (PUD) entered into a settlement agreement with regional fish managers. One of the mitigation requirements prescribed in the 1987 document was natural supplementation of spring chinook in the Wenatchee River. Since 1990, portions of the spring chinook returning to the Chiwawa River have been collected for natural broodstock. Their progeny have been reared at the East Bank Hatchery (1 km above Rocky Reach Dam), and returned to an acclimation/ release site in the Chiwawa River. Though Dryden Dam is also one of the Rock Island Hatchery Complex facilities, it is used for natural supplementation of summer chinook.

Both sport and tribal fisheries are open in the Wenatchee Subbasin. Spring Chinook sport fishing has been restricted to the Icicle River, and its confluence with the Wenatchee River, for the past couple of decades. Area and time restrictions were more relaxed before that time. There were approximately 1,000 Wenatchi Indians living in the area during the mid-19th century. From this maximum population estimate, Mullan et al. (1992) calculated that early tribal fisheries caught over 200,000 kg of salmon annually. Assuming that the major demand for salmon was satisfied by the earlier arriving sockeye salmon, they estimated that 13,783 chinook (spring and late-run) were harvested annually. Steelhead and coho salmon were assumed to make up less than 7% percent of the catch by weight. In the Walla Walla Treaty of 1855, the Wenatshapan fisheries, at present-day Leavenworth, was secured for the Wenatchi. Forty years later it was sold to build an irrigation project on the Yakima Reservation (Scheuerman 1982). Craig and Suomela (1941) state that before the Leavenworth dam was built, the Indians' fishing grounds were near the mouth of Tumwater Canyon and on Nason Creek. After construction of this dam they fished below that structure. They also presented interviews with local residents that indicate that the Indian fisheries were targeted on the fall running salmonids. Apparently, little interest was shown in capturing spring chinook. It appears that few salmon entered Icicle River during this period. The present-day tribal fishing activity is restricted to the portion of the Icicle River adjacent to the Leavenworth NFH fish ladder. In addition to catching fish, sport groups (Northwest Steelheaders) and Indian tribes receive fish from the hatchery. The sport groups use the surplus hatchery fish at public fund-raisers for the hatchery. Tribal distributions are used for traditional ceremonial and subsistence purposes.

Both natural and hatchery stocks are considered to be descended from fish trapped at Rock Island Dam between 1939-1943 as part of the GCFMP, and from lower Columbia River stocks that were introduced in the last 28 years. Unlike the Methow and Entiat rivers (or the Okanogan River which once had spring chinook, WDF et al. 1990), protracted total blockage of upstream migration of spring chinook has not occurred in the Wenatchee River. However, the sawmill, power, and irrigation dams built at the turn of the century did restrict spring migration (effect on fall migrants was severe). Possibly, spring chinook straying from the Wenatchee River contributed to the recolonization of the Entiat and Methow rivers. Marshall et al. (1995) group the natural spring chinook stocks from the Methow, Entiat, and Wenatchee subbasins into the Upper Columbia Spring Chinook Genetic Diversity Unit (GDU). None-the-less, the spring chinook natural supplementation program in the Wenatchee has been cautiously kept the within the Chiwawa River. Marshall et al. (1995) hypothesize that hatchery influences are probably decreased in the tributaries farthest from the facilities. In fact, they did find the White River spring chinook genetically distinctive within this GDU. A small number of spring chinook spawn in the uppermost spawning areas of late-run chinook, specifically in the mainstem between Tumwater Canyon and Lake Wenatchee (Fast 1988). Spring chinook are reproductively isolated from late-run chinook except perhaps in years with large run sizes where overlap is more likely from individuals on the fringes in timing and location. (Marshall et al. 1995). Late-run is a term used to describe chinook that pass Rock Island Dam after June 23rd (Peven and Mosey 1996). Mullan (1987) concluded that a distinction between a summer and a fall run was not warranted for the upper Columbia River. Late-run chinook are also referred to as summer/fall, or simply summer chinook.

John Day

Index areas for the John Day River included the upper mainstem, the Middle Fork, and the North Fork (Figure 12). These three areas include almost all of the habitat suitable for and used by spring chinook spawning in the John Day basin (Lindsay et al. 1986). From it's source in the Strawberry Mountains at an elevation near 1,800 m, the John Day River flows 457 km to its mouth at km 351 on the Columbia River (Lindsay et al. 1986). The basin includes portions of two physiographic provinces: The Deschutes-Umatilla Plateau which is a broad upland plain formed by floods of molten basalt overlain with wind-blown loess and the Blue Mountains Province which is a diverse assemblage of sedimentary, volcanic, and metamorphic rock uplifted to form rugged hills and mountains (OWRD 1986). Climate in the basin is semiarid with vegetation in lower plateaus and valleys consisting of native grasses, sage brush, and junipers, and higher elevations forested with pines and firs. The upper mainstem flows though the John Day Valley which consists mostly of irrigated pasture and hay fields (Lindsay et al. 1986, OWRD 1986). The Middle Fork flows through forest and range lands. Most of the North Fork mainstem flows through wilderness which currently provides high quality habitat but was severely degraded by mining beginning in the mid 1800s. Granite Creek (a North Fork tributary) primarily drains forest lands but valley floors are used for non-irrigated agriculture. Approximately 30% and 7% of the basin is currently managed by the U. S. Forest Service and Bureau of Land Management respectively (ODFW et al. 1990a). A large portion of the North Fork was designated as wilderness in 1984.

Extensive grazing, logging, mining, and water withdrawal has affected large portions of the John Day basin (Lindsay et al. 1986, OWRD 1986, ODFW et al. 1990a, McIntosh et al. 1994, Wissmar et al. 1994). Large-scale grazing by cattle and sheep began in the John Day basin during the late 1800s and by 1900 Shaniko became one of the world's largest wool shipping centers. Grazing has declined substantially from peaks around 1900 and in the 1930s although cattle production continues to dominate agricultural production in the basin. Significant commercial timber production began during the 1920s and increased to annual harvests which fluctuated between 200 and 400 million board feet from 1950-90. Gold extraction from stream

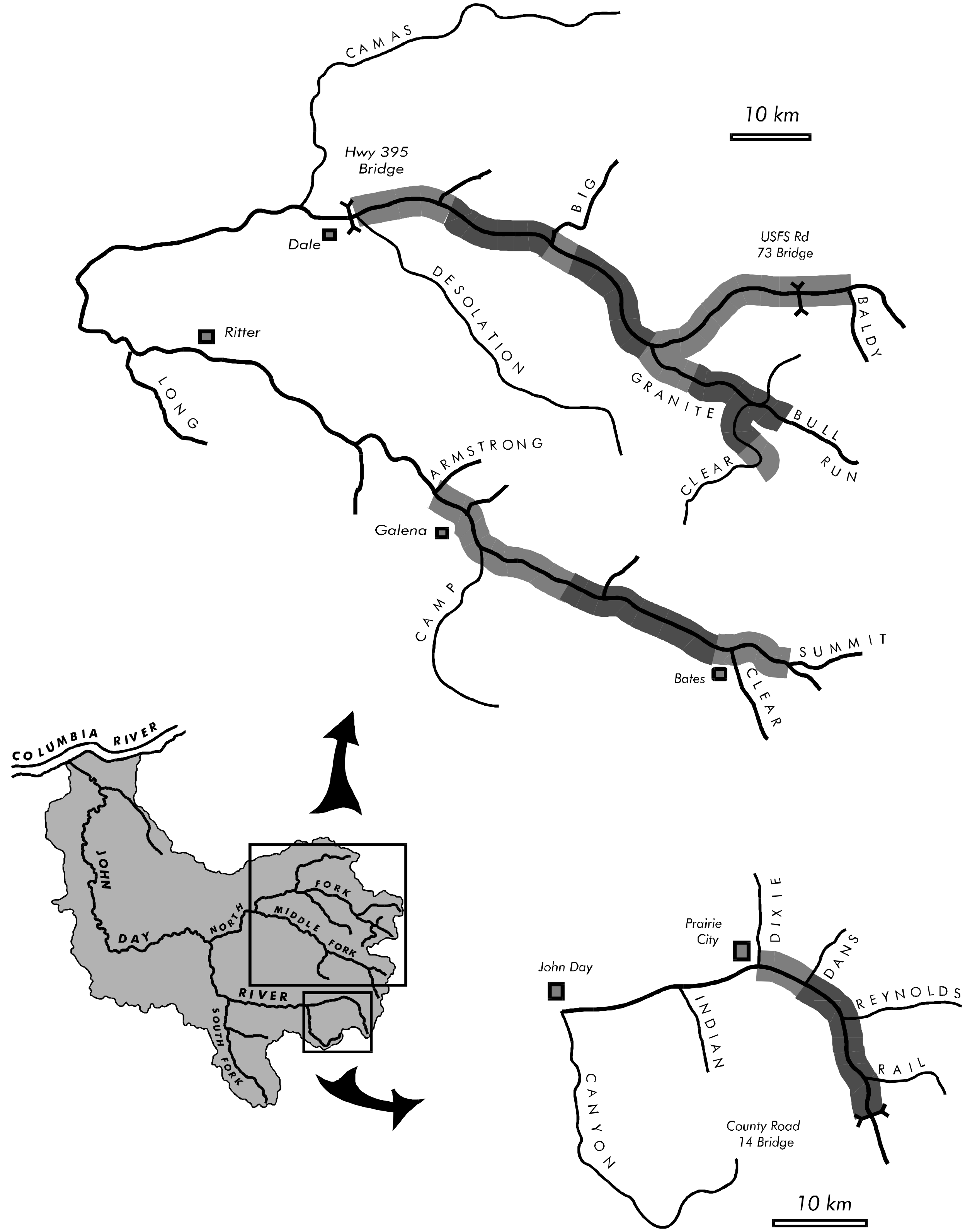

FIGURE 12. Spawning and index areas for the upper John Day River mainstem, Middle Fork, and North Fork/Granite Creek populations of spring chinook salmon in the John Day River subbasin. Index areas are denoted in dark gray and other significant spawning areas are denoted in light gray.

gravels damaged large areas in the upper mainstem from 1862 until 1946 when the last commercial dredge ceased operation. Placer mining and dredging have also affected large areas of North Fork and Middle Fork headwaters. Dredge spoils have limited recovery of riparian areas and settling ponds remain a source or toxic heavy metals. Portions of the mainstem were channelized after large floods in 1964 (Wray 1997). No large water storage or hydroelectric facilities have been constructed in the John Day basin but more than 2,500 water rights, mostly for irrigation, exist in the upper mainstem and it's tributaries. Screens are in place on significant irrigation diversions. Significant riparian fencing and other habitat improvement projects have been undertaken since 1973. Since 1985, about 60% of the mainstem above the town of John Day has been protected with riparian fences (Wray 1997).

Spawning and rearing habitat for spring chinook has been degraded and fragmented by the combined effects of human activities in the John Day basin (Lindsay et al. 1986, OWRD 1986, ODFW et al. 1990a, McIntosh et al. 1994, Wissmar et al. 1994). Sedimentation, loss of riparian vegetation, and changes in upslope plant communities have increased summer water temperature, peak flows, and the frequency of floods. Water temperatures in the upper mainstem and Middle Fork often exceeds 25°C during summer months. However, high quality spawning and rearing habitat remains in the North Fork wilderness area. Habitat conditions in the upper mainstem and middle forks are thought to be improving gradually.

Spring chinook salmon runs in the John Day River are entirely native wild stocks and have never been supplemented with hatchery fish (ODFW et al. 1990a). No hatcheries are operated in the basin and hatchery fish appear to contribute less than 1% of natural spawners. Sport fisheries for spring chinook salmon in the John Day basin have been closed since 1978 (ODFW et al. 1990a). Small numbers of spring chinook salmon have been harvested by Umatilla tribal members for subsistence uses in some years.

Deschutes

The Warm Springs River and Shitake Creek was used as an index area for spring chinook salmon in the Deschutes River subbasin (Figure 13). Most of the wild spring chinook from the basin are produced in the Warm Springs River, although before 1964 spring chinook also spawned in the mainstem Deschutes and Metolius rivers upstream from the sites of Pelton and Round Butte Dams (Newton 1973, Lindsay et al. 1989). The Warm Springs River originates in the Cascade mountain range at elevations of 1,800 m, enters the Deschutes River at Rkm 135, and an elevation of 450 m. Geology is mainly Columbia River Basalt and soils is primarily silt loam (ODFW and CTWSRO 1990). Climate is primarily semiarid with the Cascade Mountains receiving up to 250 cm of precipitation per year but the Deschutes Valley and eastern plateau receiving only 23-36 cm/yr. Most precipitation (75%) falls from October through April. Vegetation groups are primarily steppe, shrub-steppe, and juniper savanna in canyon, and plateau areas and coniferous forest in the higher elevations. Almost the entire Warm Springs and Shitake Creek Basins are within the Warm Springs Indian Reservation which is managed for multiple uses.

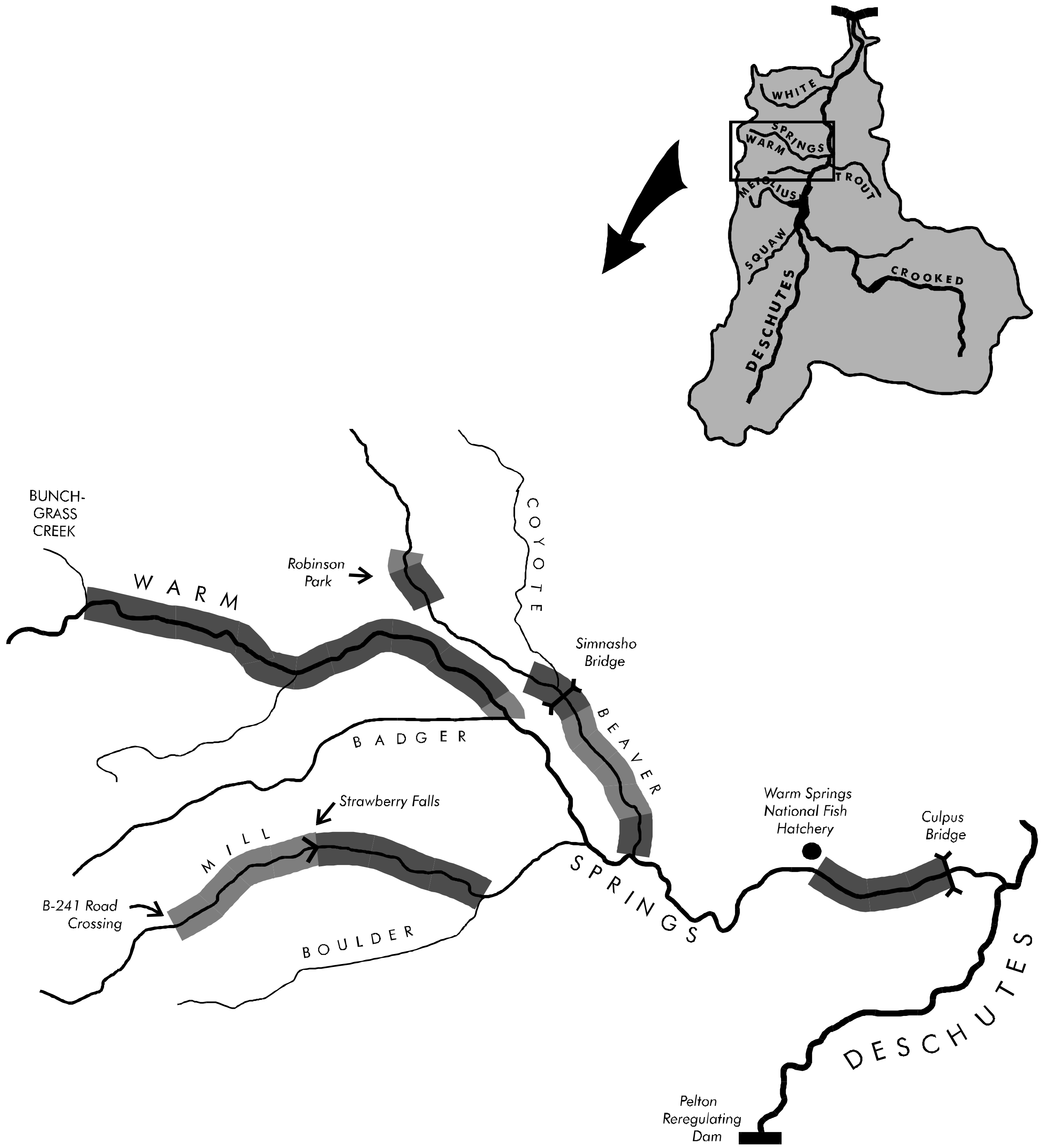

FIGURE 13. Spawning and index areas for spring chinook salmon in the Deschutes River subbasin. Index areas are denoted in dark gray and other significant spawning areas are denoted in light gray.

Grazing and timber production are currently the major land use activities on the Warm Springs Indian Reservation. Mining activities in the Deschutes basin have been largely restricted to stone, sand, and gravel and no significant operations have occurred in the Warm Spring basin. No significant impoundments have been built in the Warm Springs River or Shitake Creek basins. Pelton and Pelton reregulating dams were completed on the mainstem Deschutes River in 1958 and Round Butte Dam was completed in 1964 (upstream from the Warm Springs River). A habitat improvement program including passage improvements, instream structures, and riparian restoration was initiated in 1983 on the Warm Springs Indian Reservation (Fritsch 1986). Habitat improvements have. Between 1983 and 1986, passage improvements have opened up an additional 52 km of anadromous fish habitat.

Riparian areas throughout the Deschutes subbasin have been severely degraded by various uses during the last 100 years but riparian fencing and other habitat improvement projects in the Warm Springs River in recent years have increased vegetation, stabilized stream banks, and increased fish habitat quality and quantity (ODFW and CTWSRO 1990). Water temperature in the lower Warm Springs River often exceeds 16 °C during summer but headwaters are spring fed and provide suitable temperatures for juvenile salmon year-round (Lindsay et al. 1989). Water temperatures are unaffected by hot springs along the lower river. Summer temperature in lower Shitake Creek ranges from 14 °C to 26 °C but temperature in the Peters Pasture area averages lower than 10 °C (Fritsch 1986). Pool habitat was lacking in many portions of the Warm Springs River and Shitake Creek (Fritsch 1986). Flow and water temperature in the mainstem Deschutes River are regulated by releases from Pelton and round Butte Dams. Flow is relatively uniform averaging 4,880 cfs (range 3,130-14,800 cfs) at Pelton Reregulating Dam and 4,880 (range 3,560-23,900 cfs) at the mouth from 1976 to 1985 (Lindsay et al. 1989). Water temperature ranges from 2 °C to 19 °C during the average year.

Round Butte Hatchery and Warm Springs National Fish Hatchery have been releasing spring chinook since 1973 and 1980, and spring chinook from other hatcheries have been released periodically at Pelton Dam and in the Warm Springs River since 1958 (Lindsay et al. 1989). Round Butte Hatchery is upstream from Round Butte Dam and primarily collects and releases broodstock and smolts at Pelton reregulating Dam. Warm Springs National Fish Hatchery is on the lower Warms Springs River. Broodstock was developed from adults collected at Warm Springs Hatchery weir, Sherars Falls, and Pelton trap. The mitigation requirement from Round Butte hatchery of 1,200 adults/year is met with target releases of 270,000 smolts per year (ODFW and CTWSRO 1990). Releases include smolts trucked directly from the hatchery and smolts which are reared 4-5 months in the Pelton ladder and volitionally released. Production of spring chinook from the Warm Springs Hatchery averages about 700,000 smolts. Adults and jacks have been outplanted in 1968 and 1970. Natural spawning areas in the Warm Springs River are primarily located upstream from Warm Springs National Fish Hatchery. All hatchery fish released since 1973 have been marked and only unmarked fish have been allowed to pass the hatchery trap since 1977, except in 1982-86 when hatchery fish were allowed past the weir. Hatchery fish spawning downstream from the hatchery (Lindsay et al. 1989) or released before 1972 may have contributed to the naturally spawning stock in the Warm Springs River.

Spring chinook salmon support significant sport and tribal fisheries in the mainstem Deschutes, primarily in the 2-km section downstream from Sherars Falls. Harvest rates have generally averaged 30-40% since 1968 except for closed seasons in 1975, 1981, 1984, 1994, and 1995 to meet subbasin escapement goals.

Klickitat

Spring chinook currently spawn between Rkm 80 and Rkm 130 but most spawning is concentrated in the 6 km downstream from Castile Falls at Rkm 102 (Figure 14). Lyle Falls (Rkm 3) impeded but did not block passage before fishways were constructed in 1952 (Hymer et al. 1992). Castile Falls was a barrier to passage until fishways were completed in 1962, although passage conditions through fishways remain poor. The Klickitat River drains the east side of the Cascade range. Forests cover about 3 quarters of the basin and forestry and agriculture dominate the local economy.

Klickitat Hatchery began operations in 1952 at Rkm 67 and recent releases average 600,000 yearlings per year (Howell et al. 1985). Escapement to the basin is now primarily hatchery fish. Wild runs of spring chinook historically supported large Indian fisheries at Lyle Falls.

Wind

Spring chinook spawn in a 15-km section downstream from Paradise Creek at Rkm 40 (Figure 15). The Wind River drains conifer forests of the Cascade Range and is relatively short, steep, and cold. Much of the basin is within the Gifford Pinchot National Forest and is managed for multiple uses including timber production but significant portions are also designated as wilderness. Natural production of spring chinook in the Wind River may be limited by steep gradients and low summer flows (WDW et al. 1990b).

No spawning occurred in the Wind River until after 1956 when Shipperd Falls at Rkm 3 was laddered (Hymer et al. 1992). A naturally-spawning population was established using broodstock collected at Bonneville Dam from the aggregate upriver stock, and reared and released from Carson fish hatchery at Rkm 29. Hatchery returns to the basin typically exceed naturally-spawned fish by 10-fold.

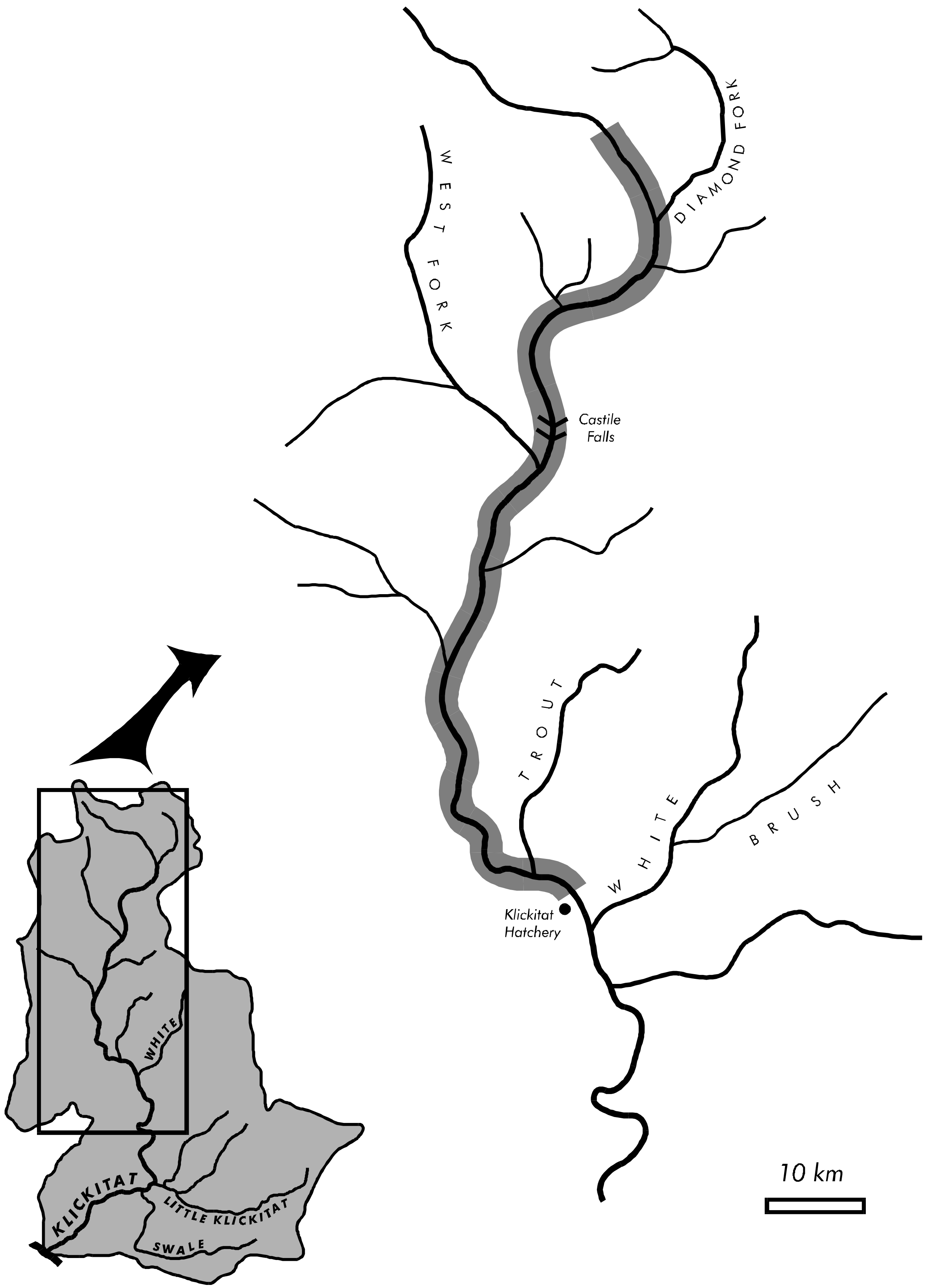

FIGURE 14. Spawning areas for spring chinook salmon in the Klickitat River subbasin.

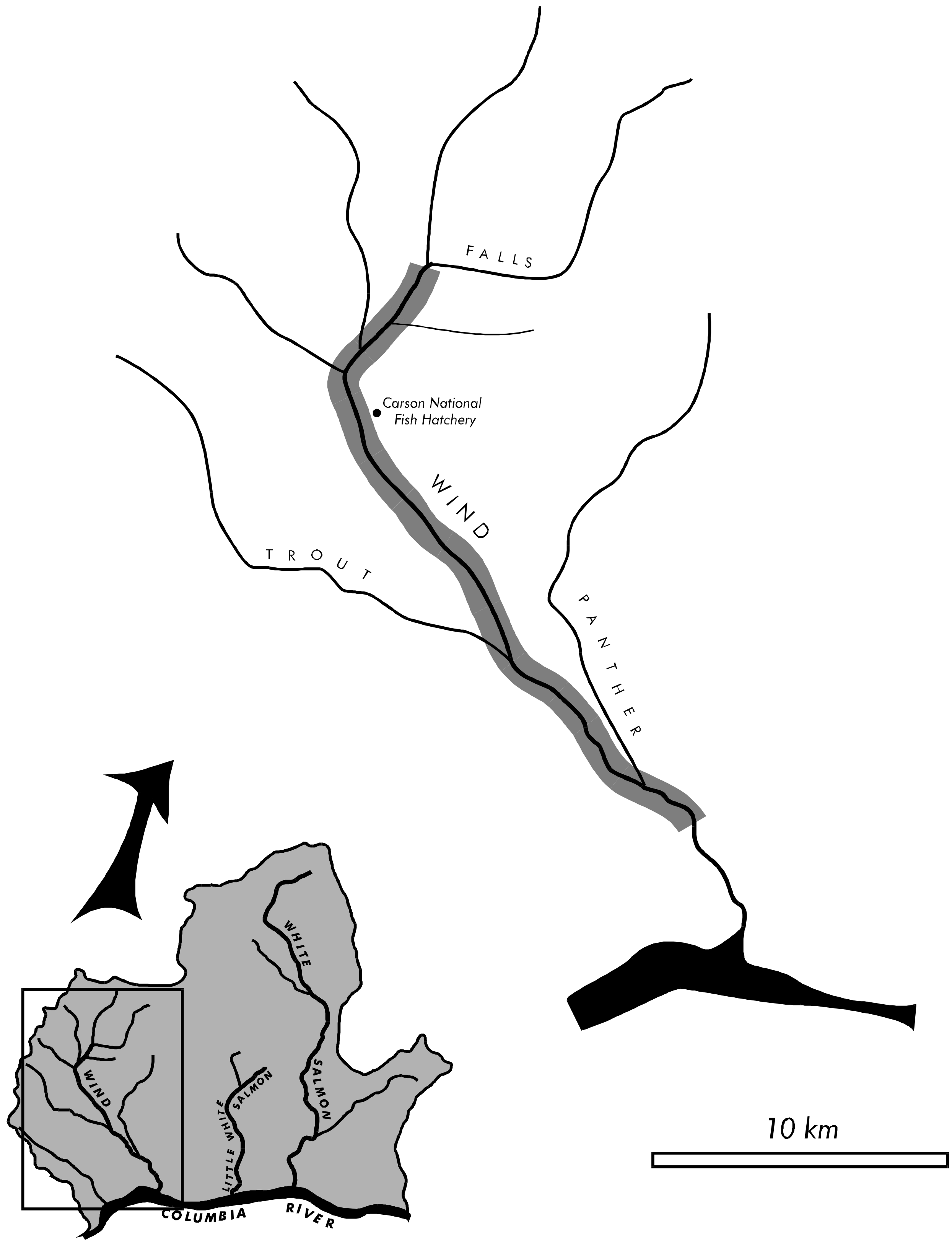

FIGURE 15. Spawning areas for spring chinook salmon in the Wind River subbasin.

Methods

Spawners and Recruits

Number of spawners was generally estimated for each year and index population as the product of peak redd counts and estimated number of fish per redd (Table 2, equations 1 and 2). Annual counts in some index areas and years were also expanded by the relative size of surveyed and unsurveyed portions of subbasin spawning areas in an attempt to represent total spawning escapement. Number of natural spawners was estimated from total spawners and hatchery fractions based on scale analyses or marks. Number returning to the subbasin was based on spawner numbers, subbasin harvest, and an assumed pre-spawning survival rate 0.90. The pre-spawn mortality rate used was a constant of about twice the percentage of unspawned females found on the spawning grounds in Snake River tributary surveys from 1953-94 (5%: Petrosky 1995); there was no indication of a trend in spawner mortality during this period Subbasin harvest rates were estimated using sport catch and run size but were often conservative because Tribal harvest data were generally unavailable before 1986. Number returning to the Columbia River was estimated from number returning to the subbasin, harvest rates in Columbia River fisheries, and upstream conversion rates of adults past Columbia and Snake River mainstem dams (Table 2, equation 15).

The recruits produced by each year's cohort of spawners (brood year) include offspring returning at proportionately older ages during subsequent run years, hence, were estimated based on age composition of returning fish (Table 2, equation 19). Thus, recruit numbers from fish spawning in brood year x will include age 3 fish returning in year x + 3, age 4 fish returning in year x + 4, and age 5 fish returning in year x + 5 (Table 2, equation 20). Age composition estimates were typically derived from length frequencies or scales collected in carcass surveys. Natural recruits to the spawning grounds include any naturally-produced fish that were removed for broodstock, and exclude any hatchery-produced fish. Recruits to the Columbia River do not include fish harvested in the ocean but ocean harvest rates for Columbia River spring chinook are near zero: <1% per cohort in Berkson (1991) and <5% per cohort in Lindsay et al. (1986). Recruits include progeny from naturally-produced parents and from naturally-spawning parents of hatchery origin.

All fish numbers referenced by this report include adults and jacks. Subbasin and year-specific information on subbasin harvest and age composition were used if available but aggregate data were used as necessary. Calculations and analyses were made using Microsoft Excel for windows version 5.0.

TABLE 2. Definitions of variables used for calculating numbers of spawners and numbers of recruits produced by each year's cohort of spawners.

Variable[1]	Definition	Equation number
A_{ltgy}	Location-, production type- and age-specific number of adults from any given population returning in any year	
l	Location where C = mouth of Columbia River, B = subbasin, and S = spawning grounds	
t	Production type where N = natural, H = hatchery	
g	Years of age (3, ..., 5)	
y	Year	
$A_{S..y}$	Total number of adults returning to spawning grounds in any year (i.e. spawners) $= (I_y / i)(k)$ for redd expansion method $= (I_y / i)$ for carcass expansion method	 [1] [2]
I_y	Index for number of spawners in any year (peak number of redds or total number of carcasses counted in subsections of available spawning area)	
i	Expansion factor based on relative sizes or frequencies of use of areas where index counts were made and other areas where spawning also occurs	
k	Average number of adults per redd	
$A_{SN.y}$	Number of naturally-produced spawners returning in any year $= A_{S..y}(1 - pH)$	 [3]
pH_y	Fraction of all fish which are of hatchery origin in any year	
pL	Fraction of fish reaching subbasin which survive death by natural causes to spawn (prespawn survival rate)	
M_y	Number of fish reaching subbasin which die from natural causes before spawning in any year $= (A_{S..y} / pL) - A_{S..y}$	 [4]
pE_{fjy}	Fishery location and type-specific exploitation rate in any year	
f	Fishery location where C = Columbia River mainstem, B = subbasin, and O = ocean	
j	Fishery type where C = commercial, S = sport, and T = tribal	
$pE_{B.y}$	Exploitation rate in subbasin in any year $= E_{B.y} / A_{B..y}$	 [5]
E_{fjy}	Fishery location and type-specific number caught and removed in any year	
$E_{B.y}$	Number caught and removed in subbasin in any year $= E_{BSy} + E_{BTy}$ or $= (A_{B..y})(pE_{B.y})$	 [6]
$pE_{C.y}$	Exploitation rate in Columbia River mainstem in any year $= E_{C.y} / (D_{1y} + E_{CCy} + E_{CSy})$	 [7]
$E_{C.y}$	Number caught and removed in Columbia River mainstem in any year $= E_{CCy} + E_{CSy} + E_{CTy}$	 [8]
B_{ty}	Production-type specific number of broodstock removed in any year	
$A_{B..y}$	Total number of adults and jacks returning to the subbasin in any year (i.e. spawners) $= (A_{S..y} + M_y + B_{Ny}) / (1 - pE_{By})$	 [9]

$A_{BN.y}$ Number of naturally-produced adults and jacks returning to the subbasin in any year
$= [(A_{S..y})(1 - pH_y) + M_y (1 - pH_y) + B_{Ny}] / (1 - pE_{By})$ [10]

pV_{dy} Conversion or survival rate past all dams between Bonneville Dam and the subbasin in any year
$= (D_{dy}) / (D_{1y} - T_{1y} - E_{cy})$ [11]

d Number of dams in the mainstem Columbia and Snake rivers downstream from the subbasin

D_{dy} Dam count of adults and jacks at the uppermost dam downstream from a subbasin in any year

D_{1y} Dam count of adults and jacks at Bonneville dam in any year

T_{dy} Number of adults and jacks turning off into tributaries between Bonneville and the uppermost dam in any year

pVD_y Per dam survival or survival rate past between two or more dams in any year
$= (pV_y)^{1/d}$ [12]

pEV_y Net survival from Columbia River mouth to subbasin
$= (pE_{Cy})(pV_y)$ [13]

$A_{C..y}$ Total number of adults and jacks from subbasin returning to mouth of the Columbia River in any year
$= (A_{B..y})(1 / pV_y)[1 / (1-pE_{Cyn})]$ [14]

$A_{CN.y}$ Number of naturally-produced adults and jacks from subbasin returning to mouth of the Columbia River in any year
$= (A_{BN.y})(1 / pV_y)[1 / (1-pE_{Cyn})]$ [15]

pG_{gy} Age-specific proportion of total number in any year (run year age frequency)
$= G_{gy} / G_{.y}$ 16]

G_{gy} Age-specific number in subsample of adults for which age was estimated

A_{SNgy} Age-specific number of naturally-spawned adults returning to spawning grounds in any year
$= (A_{SN.y})(pG_{gy})$ [17]

A_{CNgy} Age-specific number of naturally-spawned adults returning to mouth of the Columbia in any year
$= (A_{CN.y})(pG_{gy})$ [18]

R_{lgy} Location- and age-specific number of adult and jacks recruits produced in subsequent years by natural spawners in any year
$= A_{lNg(y+g)}$ [19]

$R_{l.v}$ Total location-specific number of adult and jacks recruits produced in subsequent years by natural spawners in any year
$$= \sum_{g=3}^{5} (R_{lgy})$$ [20]

R/S Recruits to Columbia River mouth per spawner ratio
$= (R_{C.v}) / (A_{S..y})$ [21]

S/S Recruits to spawning grounds per spawner ratio
$= (R_{S.v}) / (A_{S..y})$ 22]

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[1] *Period subscripts refer to totals for all categories.*

Dam Aggregates

The Columbia River aggregate includes 1939-95 dam counts of upriver spring chinook salmon for Bonneville Dam (ODFW and WDFW 1995). The Snake river aggregate includes 1962-95 dam counts of spring chinook salmon for Ice Harbor or Lower Monumental dams (whichever count was greater). Age composition for both aggregates was from commercial fisheries downstream from Bonneville Dam during April-May of 1957-76 (ODFW unpublished data). Recruits for the Bonneville aggregate were calculated as the dam ladder count plus sport and commercial harvest between the river mouth and the dam. Recruits for the Snake aggregate were calculated as the dam ladder count plus harvest and fish lost in passage of the intervening dams. Escapement for the Bonneville aggregate was calculated as dam ladder count minus commercial and Tribal harvest in the Columbia River mainstem upstream from Bonneville Dam. Escapement for the Snake aggregate was the dam ladder count. Jack and adult numbers at Bonneville dam prior to 1960 were estimated from the mean proportion of jacks and adults in commercial harvests (1960-94) and Bonneville Dam counts (1960-76). Mean age composition from 1957-76 samples was used to estimate recruitment for remaining years.

Hatchery fish in Bonneville and Ice Harbor spring chinook counts were estimated for each year from returns in every upstream tributary using expansions for mainstem dam conversion rates and harvest rates. Hatchery fish returns to tributaries were generally estimated from hatchery trap counts or by methods detailed for other index populations described in this report. Hatchery trap returns were expanded for within-tributary harvest where corresponding data were available. Wild numbers were the difference between total and hatchery numbers.

Middle Fork Salmon

The data series include 1957-1995 redd counts and adult age composition from carcass surveys. Hassemer (1993) reviewed historic redd count data, methods, and changes in transect boundaries from 1957 through 1992. The run reconstruction used Hassemer (1993) as the best standardized index of redds for 1957-1992; 1993-1995 data are from Riley and Elms-Cockrum (1995), Elms-Cockrum et al. (1995), and Elms-Cockrum (1996). Trend areas of Bear Valley, Elk, and Marsh creeks encompass most of the available spawning habitat in the respective drainages. The redd count index areas in 1957-1958 included the entire length of Sulphur Creek from the mouth to North Fork Sulphur Creek, in 1959-65 included the mouth to Sulphur Creek Ranch. Since 1966 the Sulphur Creek index area was shorter and encompassed about one quarter of the available spawning habitat in the drainage. Beginning in 1988, a second nontraditional trend area has also been counted upstream from the ranch. Trend areas in Bear Valley, Elk, and Marsh creeks were assumed (conservatively) to account for all redds in the drainage. Redd counts from Sulphur Creek were expanded to total redds in the drainage (see Appendix F for details). The expansion from redds to spawners was a constant 1.82, assuming 1 female per redd (Bjornn 1978; Kiefer and Lockhart 1994) and 55% females (subbasin planning data).

Year and area specific age composition data were from length-frequency distributions of carcasses, 1960-1994 (IDFG/CIS database; and Appendix F). When fewer than 20 carcasses were sampled per area in a given year, the aggregate MFSR sample for that year was used. No MFSR carcass data were available for 1982; the aggregate, average age composition (5:28:68 for ages 3, 4, and 5) was used in this case. Fork length classes were: ocean age 1 < 64 cm; 64 cm $\leq$ ocean age 2 < 80 cm; ocean age 3 $\geq$ 80 cm.

Hatchery fish were assumed to represent 0% of natural MFSR spawners, based on lack of coded wire tagged hatchery fish observed in carcass surveys (IDFG unpublished data). In-basin harvest rates for MFSR spring chinook were assumed equal to the estimated Snake River wild sport harvest rates for aggregate wild stocks, 1960-1978 (Horner and Bjornn 1981). Sport harvest since fisheries were closed in 1979 was assumed to be zero. No attempt was made to account for Tribal subbasin harvest in the run reconstructions.

South Fork Salmon

The data series include 1957-1995 redd counts and adult age composition from carcass surveys (Hassemer 1993; Riley and Elms-Cockrum 1995; Elms-Cockrum et al. 1995, Elms-Cockrum 1996). Trend areas from Poverty Flat downstream to the East Fork SFSR were assumed (conservatively) to account for all redds in that part of the SFSR drainage. Redd counts from the Johnson Creek trend area accounted for 92% of the redds below the migration barriers near Trout Creek; the Johnson Creek index area redds were expanded to total redds in the drainage below Trout Creek (see Appendix G for details). The expansion from redds to spawners was a constant 2.31, assuming 1 female per redd (Bjornn 1978; Kiefer and Lockhart 1994) and 43% females (subbasin planning data).

Year and area specific age composition data were from length-frequency distributions of carcasses, 1960-1995 (IDFG/StreamNet database; and Appendix G). When fewer than 20 carcasses were sampled per area in a given year, the aggregate SFSR sample for that year was used. The aggregate, average age composition for the SFSR was 16:39:45 for ages 3, 4, and 5. Fork length classes were: ocean age 1 $<$ 64 cm; 64 cm $\leq$ ocean age 2 $<$ 80 cm; ocean age 3 $\geq$ 80 cm.

Hatchery fish were assumed to represent 0% of natural spawners based on few CWT observations during carcass surveys in these index areas; thus recent recruitment would be overestimated if substantial dropout or straying of hatchery fish has been occurring. In-basin harvest rates for SFSR summer chinook were assumed equal to the estimated Snake River wild sport harvest rates for aggregate wild stocks, 1960-1964 (Appendix G). Sport harvest on wild SFSR chinook has been closed since 1965. SFSR summer chinook were previously harvested in sport fisheries in the tributaries, mainstem SFSR and in the Salmon River. Horner and Bjornn (1981) estimated that, on average, 22% of Idaho spring/summer chinook sport harvest occurred in the SFSR drainage from 1959 to 1964. Tribal harvest also occurred historically on SFSR chinook; since 1981 SFSR tribal harvests ranged from 0 to 95 wild and 0 to 207 hatchery fish (TAC 1996). No attempt was made to account for Tribal subbasin harvest in the run reconstructions.

Imnaha

The data series includes estimates of escapement based on redd counts from 1949-50 and 1952-95 in the Imnaha mainstem and 1964-95 in Big Sheep and Lick creeks. Data from 1949-75 are from Oregon Fish Commission annual reports (Donaldson and Schoning 1949, Donaldson and Clutter 1950, Gunsolus and Herman 1952, Gunsolus et al. 1953, Loeffel and Narver 1958, Loeffel and Jones 1958, Korn and Carney 1958, Burck 1958a, 1958b, Herrman et al. 1959, Burck and Thompson 1960, Thompson and Montagne 1961, Weiss and Herrman 1962, Weiss and Demory 1963, Demory 1964, Demory 1965, Young 1967, Bohn 1967, Young 1969, Ramsey

1969, Ramsey 1970, Hirose 1971, Bennett and Hirose 1972, Bennett 1973, Bennett 1975a, 1975b). Data from 1976-85 are from ODFW District annual reports (Witty 1976,...,1985). Data since 1986 are from ODFW research staff and reports (R. Messmer and M. Keefe, personal communication; Keefe et al. 1996). Spawner numbers were estimated from redd counts in index areas with an expansion for other spawning areas based on average proportions inside and outside index areas during 1986-95. Imnaha basin counts index counts were peak counts, hence, are minimum estimates of escapement to the basin. Expansions for the entire spawning period since 1986 were not included because comparable information was not available during earlier years. Estimates of average fish per redd (3.2) were based on 9 annual estimates above weirs in Lookingglass Creek and Imnaha River (personal communication from M. Keefe, ODFW research biologist).

Age composition from 1961-present was based on scale samples collected from carcasses observed during annual spawning ground surveys (1961-75 reported in Oregon Fish Commission Annual Reports; 1976-85 from L. Borgerson, ODFW; 1986-94 from M. Keefe, ODFW). Age composition in 1953-60 was based on length-frequency data for carcasses reported in Oregon Fish Commission Annual Reports and an age-length key developed from age and length data for 1961-72. A pooled-year estimate of age composition was used for 1949-52 and when year-specific sample size was less than 20. A pooled area sample was applied to the Imnaha mainstem and the Big Sheep/Lick populations.

Hatchery fish proportions in the Imnaha River from 1985 to present were proportions on spawning grounds from weir counts of marked and unmarked fish and marked-unmarked proportions of hatchery-reared smolts (Carmichael and Messmer 1985, Carmichael et al. 1986, 1987, 1988, Messmer et al. 1989, 1990, 1991, 1992, 1993, and personal communication, M. Keefe, ODFW,). Hatchery fish proportions in Big Sheep and Lick creeks were based on Imnaha weir counts. In-basin exploitation rates for the sport fishery were estimated based on license tag returns relative to estimated escapement to the Imnaha mainstem, Big Sheep Creek, and Lick Creek (Koski 1963, Koski 1972, Berry 1980, Anonymous 1989). Tribal harvest was assumed equal to sport harvest (personal communication, K. Witty, ODFW).

Grande Ronde

This data series includes estimates of escapement based on redd counts conducted between 1949 and 1954. (Surveys were not completed in all areas and years before 1964.) Data from 1949-75 are from Oregon Fish Commission annual reports (Donaldson and Schoning 1949, Donaldson and Clutter 1950, Gunsolus and Herman 1952, Gunsolus et al. 1953, Loeffel and Narver 1958, Loeffel and Jones 1958, Korn and Carney 1958, Burck 1958a, 1958b, Herrman et al. 1959, Burck and Thompson 1960, Thompson and Montagne 1961, Weiss and Herrman 1962, Weiss and Demory 1963, Demory 1964, Demory 1965, Young 1967, Bohn 1967, Young 1969, Ramsey 1969, Ramsey 1970, Hirose 1971, Bennett and Hirose 1972, Bennett 1973, Bennett 1975a, 1975b). Data from 1976-85 are from ODFW District annual reports (West 1976,...,1985). Data since 1986 are from ODFW research staff and reports (R. Messmer and M. Keefe, personal communication; Keefe et al. 1996). Spawner numbers were estimated from redd counts in index areas with an expansion for other spawning areas based on average proportions inside and outside index areas during years when extensive surveys were conducted. Index counts were peak counts, hence, are minimum estimates of escapement to the basin. Expansions for the entire spawning period since 1986 were not included because comparable information was not available during earlier years. Estimates of average fish per redd (3.2) were the average of 9 annual estimates above weirs in Lookingglass Creek and Imnaha River (personal communication from M. Keefe, ODFW research biologist).

Age composition from 1961-94 was based on scale samples collected from carcasses observed during annual spawning ground surveys (1961-75 reported in Oregon Fish Commission Annual Reports; 1976-85 from L. Borgerson, ODFW; 1986-94 from M. Keefe, ODFW). Age composition in 1953-60 was based on length-frequency data for carcasses reported in Oregon Fish Commission Annual Reports and an age-length key developed from age and length data for 1961-72. A pooled-year estimate of age composition was used for 1949-52 and when year-specific sample size was less than 20. Samples from all areas were pooled because of low area-specific sample sizes in most years.

Hatchery fish proportions from carcasses on the spawning grounds were based on scale pattern analysis or marked to unmarked ratios in recent years when all hatchery fish have been marked (Carmichael and Messmer 1985, Carmichael et al. 1986, 1987, 1988, Messmer et al. 1989, 1990, 1991, 1992, 1993, and personal communication, M. Keefe, ODFW). Exploitation rates were from license tag returns for the sport fishery in the Minam River (Koski 1963, Koski 1972, Berry 1980, Anonymous 1989) and are conservative because they do not include limited harvest in the Wallowa and Grande Ronde rivers downstream from the Minam River. Tribal harvest was assumed equal to sport harvest (personal communication, R. Carmichael, ODFW).

Methow

The data series includes 1960-95 estimates of escapement to the subbasin based on redd counts (Schwartzberg and Roger 1986, Scribner et al. 1993, and personal communication from Hubble, Yakama Indian Nation). Index areas include 40 km within the mainstem Methow, Chewuch, Lost, Twisp and Early Winters Creeks. For years prior to 1987, best redd counts were derived from an expansion of index counts by the average ratio of index redds to total redds observed during comprehensive surveys conducted from 1987-present (comprehensive surveys incorporated an additional 142 km of spawning habitat). For the recent years with comprehensive temporal/spatial surveys, the peak count of redds were summed across all reaches to derive the best estimate of redds. Fish per redd expansions were based on weir and redd counts from the Chiwawa River in the Wenatchee Basin.

Age composition was based on 1982-94 Winthrop NFH returns (Pettit 1995a), and unpublished age composition for return year 1995 from Pettit. The brood year age composition was adjusted for the size of the hatchery release, and converted back to return year format. . The average adjusted return year age composition for 1984-95 was used for years prior to 1984 (note that for return year 1984 age composition no age 6 fish can be assumed). Given the availability of jack (3-years old) composition at the nearest Columbia River hydropower project for years prior to 1984, and the potential that natural spawner jack proportions may be closer to dam jack proportions than hatchery jacking rates, the age-3 composition was taken from Corps dam count information. The adult age composition was therefore adjusted accordingly, retaining the ages 4, 5, and 6 ratios previously calculated.

Winthrop National Fish Hatchery first released yearling spring chinook from the 1974 brood; therefore, straying hatchery adults were not accounted for until return year 1978. The number of hatchery fish in natural spawning areas was estimated as 25% of the hatchery rack return because few marked fish were available for more accurate estimates. Hatchery fish proportions were thought to be moderate based on distance between the hatchery and natural spawning area, numbers prior to hatchery production, and low rack returns thereafter. No sport or tribal fisheries were open in the Methow basin during the period of record. Prespawn survival was set at 90 percent for both the natural and hatchery fish.

Entiat

The data series includes 1955-95 estimates of escapement to the subbasin based on actual or estimated redd counts. French and Wahle (1965) reported live/dead fish counts for 1955-60. Using the 1960 ratio of redds to fish, redd counts for the index area could be calculated for 1955-59. The 1960-84 index redd count data is reported in Swartzberg and Roger (1986). These values were confirmed by review of the Washington Department of Fish and Wildlife, Wenatchee, files. The 1984-95 redd counts were also taken from the files. LaVoy (1995) reported part of this information, and described how the missing redd count in 1979 was estimated (using the average ratio of Entiat redd counts to inter-dam counts of spring chinook between Rocky Reach and Wells dams for 1977, 78, 80 and 81). Index areas include 11 km within the mainstem Entiat. For years prior to 1994 (excluding 1979), best redd counts were derived from an expansion of index counts by the ratio of index redds to total redds observed during the comprehensive survey conducted in 1994 (that comprehensive survey incorporated an additional 11.4 km of mainstem Entiat spawning habitat). For the 1994-95 surveys, the peak count of redds were summed across all reaches to derive the best estimate of redds. While multiple surveys were conducted in 1995, there was no survey timing information available that would allowed us to determine if a temporal expansion factor should be applied to past surveys (in addition to the spatial-oriented expansion derived in the 1994 single full-area survey). In 1995, a small portion of the Mad River was added to the survey bringing the total distance surveyed up to 23 km. Fish per redd expansions were based on weir and redd counts from the Chiwawa River in the Wenatchee Basin.

Age composition was based on 1983-94 Entiat NFH returns (Pettit 1995a), and unpublished age composition for return year 1995 from Pettit. While Pettit (1995a) contained some data back to return year 1980, and enough data to derive a brood year 1979 age composition, we began our brood year tables with 1980 as Pettit had done. The brood year age composition was adjusted for the size of the hatchery release, and converted back to return year format. The average adjusted return year age composition for 1985-95 was used for years prior to 1985 (note that for return year 1985 age composition no age 6 fish can be assumed). Given the availability of jack (3-years old) composition at the nearest Columbia River hydropower project for years prior to 1985, and the potential that natural spawner jack proportions may be closer to dam jack proportions than hatchery jacking rates, the age-3 composition was taken from CORPS dam count information. The adult age composition was therefore adjusted accordingly, retaining the ages 4, 5, and 6 ratios previously calculated.

Hatchery records, for return years 1975-79, do not indicate clearly that returning fish were actually collected. It is assumed that they were likely collected with less efficiency, therefore the number of hatchery fish in natural spawning areas was estimated as 20% of the hatchery rack return for this period, and 10% of the hatchery rack return since 1980. These are crude estimates because few marked fish were available for more accurate estimates. Natural spawning by hatchery fish was assumed to be minor because of good attraction flows at the hatchery and wide separation between the hatchery and natural spawning areas. In-basin harvest has been minimal. Seasons have been closed in all years except 1986-87 when brief seasons near the hatchery were thought to have harvested no wild fish (WDF et al. 1990a). Prespawn survival was set at 90 percent for both the natural and hatchery fish.

Wenatchee

The data series includes 1958-95 estimates of total escapement based on annual redd counts in the Wenatchee and Icicle rivers with expansions based on additional surveys in 1958-69 and 1981-95 (Peven and Mosey 1996). Fish per redd expansions were based on weir and redd counts from the Chiwawa River in the Wenatchee Basin. Age composition was based on hatchery returns to the Icicle River and wild sport harvest for 1979-95 (Pettit 1996), the composite upriver stock estimated for 1973-78 (Pettit 1995b), and the 1973-95 average for 1958-72. Carcass samples from 1990-93 surveys showed similar age compositions between hatchery and naturally-spawning populations except for slightly more 4- and 5-year olds in the wild (Peven and Mosey 1996).

Natural spawners outside Icicle Creek were estimated to include 5% of the unharvested Leavenworth National Fish Hatchery return based on carcass sampling in 1993. Spawner numbers were also corrected for natural broodstock removed at the Chiwawa weir and gaffed from spawning grounds. "Wild" catch in mainstem Wenatchee sport fisheries were calculated as 60% of total (from angler tag reports) in 1977-78 and 1980 during liberal time and area seasons. In prior years all harvest was wild. Since 1980 harvest of wild fish was estimated from scale analysis (Pettit 1995a).

John Day

The data series includes 1959-95 estimates of total escapement based on annual redd counts. Spawner numbers were estimated from redd counts in index areas which were surveyed annually from 1959 to present and an expansion for other spawning areas based on redd numbers inside and outside index areas during 1978-85 (Lindsay et al. 1986). Peak redd counts from 1959-85 are from Lindsay et al. (1986). Expansions were based on redds per mile from 1959-76 because of corrections to peak counts made by Lindsay et al. (1986). Redd counts from 1986-94 were a personal communication from T. Unterwegner (ODFW District Biologist). Escapement in each of the four index areas was estimated using area-specific expansion factors and total escapement to the subbasin was the total in all four areas. North Fork mainstem and Granite Creek areas were pooled to represent a single population because spawning areas were contiguous. Missing values for counts in the North Fork mainstem during 1959-63 and the Middle Fork in 1959 were replaced with counts based on the relative frequencies in those and other areas in subsequent years. Estimates of average fish per redd (3.2) were based on 9 annual estimates above weirs in Lookingglass Creek and Imnaha River (M. Keefe, ODFW, personal communication). Small differences between our estimates and those reported in Lindsay et al. (1986) and TAC (1996) result from: a) our use of 3.2 fish/redd and 90% prespawn survival (net expansion of 3.6) rather than the flat 3.0 fish per redd; and b) our use of area-specific rather than the area-pooled expansion factors.

Age composition for 1978-85 was from Lindsay et al. (1985); 1986-88 was from Olson and Sampson (1989); 1991-93 was from D. Case, ODFW, personal communication; and 1994 was from L. Borgerson, ODFW, unpublished data. Age composition was based on area and year-specific samples where sample size was 20 or more. Average population-specific age frequency from years with 20 or more samples were used for all years where sample size was less than 20 except for 1990-93 when a pooled-area sample was applied. Hatchery fish were assumed to represent 1.7% of natural spawners based on unpublished data from 1994 carcass surveys (L. Borgerson, ODFW, personal communication). Note that recruitment estimates based on observed age frequencies differ slightly from those calculated by Lindsay et al. (1986) using a constant 5:90:5 ratio for age 3 (jacks), age 4, and age 5 numbers. In-basin exploitation rates were based on license tag returns for the sport fishery (Koski 1963, Koski 1972, Berry 1980, Anonymous 1989) and on a personal communication from T. Unterwegner (ODFW) for treaty fisheries.

Deschutes

The data series includes 1969-95 estimates of escapement based on redd counts. Data from 1969-86 are summarized in Lindsay et al. (1989). Data from 1987-95 are a personal communication from M. Fritsch, Confederated Tribes of the Warm Springs Reservation of Oregon. Spawner numbers were estimated from redd counts in index areas with an expansion for other spawning areas based on average proportions inside and outside index areas. Estimates of fish per redd were based on estimated redds and number of fish released past the Warm Springs Hatchery weir. Pre-spawning mortality was estimated using the technique of Lindsay et al. 1989. The high pre-spawning mortality in the early 1980s was coincident with high mortality at Warm Springs National Fish Hatchery (WSNFH) from bacterial kidney disease (Cates 1981). All of the hatchery and wild adults arriving at WSNFH have been inoculated with erythromycin each year since 1982. The elevated level of pre-spawning mortality is attributable to injection and handling of wild and hatchery fish at the hatchery (Lindsay et al. 1989). Age composition from 1975-present was based on scale samples collected each year. Age composition before 1975 was based on the 1975-95 average.

Hatchery fish proportions were marked and unmarked proportions at the Warm Springs hatchery weir (all hatchery releases were marked). Annual harvest rates were estimated for recreational and tribal fisheries from 1979-95. The average of annual rates, when fisheries were open, was used for years before 1979.

Klickitat

The data series includes 1966-95 estimates of escapement to the subbasin based on redd counts and expansions done by Washington Department of Fish and Wildlife prior to 1980, and those done by the Yakama Indian Nation since. Years prior to 1966 were excluded based on surveys being limited, missing Klickitat State Hatchery records (for 1963), and changes and development of fishways in the 1950s. Pettit (1996) reports the escapement estimates, and the corresponding expansion factors used, since 1977. Schwartzberg and Roger's (1986) historical redd and fish counts appear to be wrong or missing when compared to the source (WDFW Battle Ground survey card file going back to 1944), therefore for 1966-76 numbers were taken from the survey cards and expanded by an average expansion (for 1966-87 excluding 1967,72 and 74). After 1976, the expansions vary from year to year, basically consisting of a fish to redd expansion component and a counting efficiency factor. Area expansions are typically not applied as the surveys extend the length of the mainstem spawning area (McCormick Meadows at Rkm 128 to Parrott's Bridge at Rkm 79). In more recent years occasional surveys by either WDFW or YIN have gone down as far as Twin Bridge at Rkm 29.3 with less than three dozen redds found in six years between Parrott's Bridge and Leidel Bridge at Rkm 51.5, and none between Leidel and Twin bridges. The relationship between redds/mile and fish/mile was used to fill in years when redd counts were not taken (1972 and 1974). The source for the escapement estimate for 1988, as reported in Pettit (1996), has not been identified. No spawning survey was recorded for that year (but perhaps survey records have been lost). Though it is the highest escapement since 1966, the corresponding recruits per spawner seems reasonable and consistent with surrounding years.

Hatchery fractions were derived by using the ratio of marked to unmarked fish returning to Klickitat State Hatchery to expand marks on the spawning ground. In years were no marks existed, we used the average ratio of hatchery fish on the spawning ground to hatchery fish returning to the hatchery (the average developed from years when marks were available) multiplied by the number of fish returning to the hatchery, to estimate hatchery fish to the spawning ground. Age composition was based on Pettit (1995a) for 1988-94, and a pooled-year average for years before 1988 (and for 1995).

Wind

The data series includes 1970-95 estimates of escapement to the subbasin based on peak live/dead fish counts and expansions done by Washington Department of Fish and Wildlife. Years prior to 1970 were excluded based on surveys being limited, no natural spawner escapement estimates in 1968 and 1969, and development of fishways in the 1950s. Pettit (1996) reports the escapement estimates, and the corresponding expansion factors used. Schwartzberg and Roger's (1986) historical redd and fish counts reference the WDFW Battle Ground survey card file going back to 1944, however currently the file does not show spring chinook surveys in the Wind Subbasin prior to 1980. Expansions vary from year to year, basically consisting of a fish to redd expansion component and a counting efficiency factor. Area expansions are typically not applied as the surveys extend the length of the mainstem spawning area (from Paradise Creek at Rkm 40.2 down to Bear Creek Camp Ground at Rkm 26.4). More recently, surveys by both snorkel and ground count have covered the river down to the mouth area.

Hatchery fractions were back calculated from estimates of hatchery fish on the spawning ground derived by using various ratios between marked and unmarked fish, and between hatchery returns and natural spawners. Mark recoveries in the subbasin indicated that we only needed to concern ourselves with the straying of fish from the Carson NFH. When marked fish were recorded on the spawning ground, the hatchery adult mark rate (i.e., the ratio of marked to unmarked fish returning to the hatchery) was used to expand the marked fish counts on the spawning ground to an estimate of hatchery fish on the spawning ground. During years when marked fish appeared on the spawning grounds but not in the hatchery, the hatchery juvenile mark rate (i.e., the portion of the corresponding release that was marked) was used to expand the spawning ground marked fish. In many years no marked fish were found on the spawning ground. For this situation, we estimated the number of hatchery fish on the spawning grounds by multiplying the number of fish returning to the hatchery that year by the average ratio of hatchery fish on the spawning ground to hatchery fish returning to the hatchery (from years when marks were available). Age composition was based on Pettit (1995) for 1988-94, and a pooled-year average for years before 1988. The 1994 age composition was assumed for 1995.

Mainstem Harvest and Conversion

Harvest rates in mainstem fisheries were estimated (Table 2, equation 7) from total harvest in commercial, sport, and treaty fisheries, and Bonneville Dam ladder counts reported in WDFW and ODFW (1995). For purposes of Klickitat, John Day, and Deschutes River escapement calculations, all Zone 6 (Bonneville Dam to McNary Dam) harvest of spring chinook salmon can be assumed to occur in the Bonneville and lower The Dalles reservoirs (Steve King, ODFW, personal communication). Conversion rates refer to the fraction of returning fish passing a series of dams and exclude numbers turning into tributaries along the way and numbers harvested in mainstem fisheries (Table 2, equation 11). Rates are estimates of fish survival between one or more dams and provide estimates of unaccounted losses.

Conversion rate calculations were based on tributary escapements estimated for stocks included in this report if available and otherwise from TAC (1994) for 1979-1994 and M. Matylewich (Columbia River Inter-Tribal fish Commission, personal communication) for 1960-1978. Tributary escapements prior to 1959 were generally based on year-specific Bonneville dam counts and proportional run sizes in each tributary from 1970-1977 (Appendix A). Exceptions include: Wind River where Shipperd Falls at RM 2 blocked migration before 1956 and releases of yearlings from Carson Hatchery began in 1960 (Howell et al. 1985); Little White Salmon River where natural production was blocked by falls at the mouth and hatchery releases began in 1967 (Howell et al. 1985); White Salmon River where Condit Dam at RM 3.3 blocked natural spawners since 1917 and hatchery releases started in 1982 (Hymer et al. 1992); Hood River where counts were made at Powerdale Dam in 1963-1971 (ODFW and CTWSRO 1990) and 1992-present (Olsen et al. 1995); John Day River where the 1959-67 run years provided an estimate of pre-Celilo Falls inundation returns; and Umatilla River where spring chinook were extirpated by 1914 but reintroduction produced adult returns beginning in 1992 (CTUIR and ODFW 1990). Our estimates of conversion rates differ slightly from similar calculations in TAC (1996) because we used combined adult and jack counts for dams, fisheries, and tributary escapement while TAC (1996) excluded jacks from dam and fishery counts. In addition, we did not include recent revisions in calculation methods to equitably apportion conversion rates to tributary escapements where the conversion rate refers to passage past multiple dams and tributaries (TAC 1996). This change results in a <4% underestimation of the Bonneville to McNary conversion rate. Conversion rates greater than 1 were fixed at 1.

Results

Run reconstructions are detailed in appendix tables. Appendix A describes mainstem adult passage conversion rates used to estimate numbers of spring and summer chinook salmon at the Columbia River mouth from dam counts, mainstem harvest rates, and the number returning to each subbasin. Expansion factors for each basin were taken from different columns in Appendix A depending on number of dams and fisheries encountered between the Columbia River mouth and the natal subbasin. Appendix B describes spawner and recruit calculations for aggregate upriver stocks. Recruit per spawner calculations for each subbasin index population are summarized in Appendix Tables C.4-M.4. Conversion rates, spawner numbers, age frequencies, and tributary exploitation rates used in spawner recruit calculations were linked to the main spreadsheet table for each population from other sheets/tables which are also included in the Appendices. Appendix Tables C.1-M.1 calculate run year spawner numbers from redd or carcass counts. Appendix Tables C.2-M.2 calculate run year age frequencies from number of known age fish. Appendix Tables C.3-M.3 calculate run year harvest rates in subbasin fisheries from estimated catch and total number of fish returning to the basin. Formats and formulas are consistent in the main spawner-recruit tables among all index populations (C.4-M.4). Formats and formulas vary in the other sheets/tables to account for differences in data availability among index populations. Key numbers derived in other sheets/tables for transfer to the main spawner-recruit table are uniformly shown in the left-hand columns of the subsidiary sheets.

Spawner data included a total of 832 year- and population-specific observations (Table 3). Data were available from all years since 1970 for all 22 index populations (except for missing observation for Lookingglass Creek in 1984). Before 1970, Snake River populations were better represented than were mid- and lower-Columbia populations. Year-specific age data was available for each subbasin for most years (72%), although in several cases, subbasin average data were applied to several populations. Age data availability was not evenly distributed among periods and portions of the basin (Table 3). For instance, no year-specific age data was available for lower or upper Columbia populations before 1970. The incidence of hatchery fish in naturally-spawning index populations increased after 1970 in some lower and mid-Columbia populations and after 1980 in some Snake River populations (Table 3).

Table 4 summarizes mean values for several key components of run reconstructions by index population. Because average values include only years where spawner data were available, some of the differences among populations result from differences in time interval. In addition, averages often hide temporal trends. Average redd (or carcass) counts ranged from 25 in Big Sheep and Lick Creeks to over 450 in Bear Valley and Elk creek populations. Expansion factors for surveys in only a subset of a population's spawning area ranged from 1 (no expansion) to just over 3. In some cases where no expansion was applied, surveys included the entire population while in others, a suitable expansion factor was not available. Estimates of spawner per redd were typically applied as a constant for all years in a given subbasin based on the average of estimates for a few years. Average values for exploitation rates reflect harvest before 1975 with limited mainstem and tributary fisheries since.

Index populations of spring chinook accounted for an average of 55% of the aggregate spring run of natural spawners above Bonneville Dam based on estimated recruits to the Columbia River mouth from 1970-90 brood years when data were available for all index populations. The aggregate stock of naturally-spawning spring chinook averaged 59,031 at Bonneville Dam from 1939-90. The Snake River aggregate stock of naturally-spawning spring chinook averaged 19,611 from 1962-90. Average annual spawner numbers ranged from 201 in Big Sheep and Lick creeks to 2,697 in the Wenatchee River (Table 5). Annual recruits to the Columbia River mouth averaged 115,504 and 39,085 for the Bonneville and Snake aggregates, and ranged from 225 for the Wind River to 7,033 for the Methow River. Recruits per spawner averaged 1.6-1.7 for the aggregate stocks and population averages ranged from 0.8 for the Wind River to 3.9 for the Warm Springs River (geometric means). Spawner number, recruit number, and recruits per spawner were all extremely variable over the period of record. Coefficients of variation were generally within 50-150% for spawner and recruit numbers and within 100-300% for recruits per spawner (Table 4).

Cursory exploration of pooled data for each stock identified significant linear correlations ($p<0.05$) with correlation coefficients of at least ±0.20 for years with spawners, recruits, Ln(recruits/spawner), Bonneville count, and Ice Harbor count; of spawners with recruits, spawning area size, Bonneville count, and Ice Harbor count; of recruits with Ln(recruits/spawner) and spawning area size; of Ln(recruits/spawner) with Bonneville count; of ocean distance with dam number and spawning area size; and of Bonneville and Ice Harbor counts (Table 6). Correlation coefficients exceeded ±0.50 only for spawners:recruits, spawners:spawning area size, recruits:spawning area size, dam number:ocean distance, and Bonneville count:Ice Harbor count. Population-specific spawner estimates were significantly correlated with Bonneville and Ice Harbor dam counts in all Snake and upper Columbia river populations except Bear Valley/Elk and Poverty Flat (Table 7). Lower river spawner numbers were generally not significantly correlated with dam counts (except for the John Day North Fork/Granite Creek population. Spawner numbers and Ln(recruits per spawner) generally declined over time (Figures 16A and 16B). Recruits generally increased and Ln(recruits per spawner) generally decreased with increasing spawners although patterns were hard to discern in plots of pooled observations which mix populations of widely varying spawner-recruit relationships (Figure 16C and 16D).

TABLE 3. Spawner count availability, age composition availability, and hatchery contribution for index populations of wild spring and summer chinook salmon in Idaho, Oregon, and Washington.

	Years						
Region	1940-49	1950-59	1960-69	1970-79	1980-89	1990-95	Total
	Number of year and population-specific observations						
L. Columbia	0	3	35	60	60	36	194
Snake	2	61	122	130	130	78	523
Mid Columbia	0	7	30	30	30	18	115
Total	2	71	187	220	220	132	832
	Percentage of observations with year and subbasin-specific age composition data						
L. Columbia	--	0	0	35	68	75	46
Snake	0	64	100	89	81	83	85
Mid Columbia	--	0	0	67	100	83	57
Total	0	55	65	72	80	81	72
	Percentage of observations where hatchery fraction on spawning grounds ≥ 5%						
L. Columbia	--	0	6	28	35	19	24
Snake	0	0	0	0	21	62	14
Mid Columbia	--	0	3	33	97	83	48
Total	0	0	2	12	35	53	21

TABLE 4. Mean values for components[1] of run reconstructions based on available years of spawner data for index populations of wild spring and summer chinook salmon in Idaho, Oregon, and Washington. (Values constant in all years are in italics.)

Subbasin, population	I	i	k	pH	pL	pE_B	pE_C	pV	pG_3	pG_4	pG_5	pG_6
Middle Fork Salmon												
Bear Valley/Elk	452	*1*	*1.82*	*0*	*0.90*	0.07	0.27	0.59	0.04	0.28	0.68	0
Marsh	224	*1*	*1.82*	*0*	*0.90*	0.06	0.32	0.62	0.03	0.26	0.72	0
Sulphur	58	2.68	*1.82*	*0*	*0.90*	0.07	0.27	0.59	0.05	0.27	0.68	0
South Fork Salmon												
Poverty Flat	408	*1*	*2.31*	*0*	*0.90*	0.04	0.13	0.66	0.15	0.35	0.50	0
Johnson	137	*1.09*	*2.31*	*0*	*0.90*	0.04	0.13	0.66	0.11	0.36	0.53	0
Imnaha												
Mainstem	213	1.61	*3.2*	0.07	*0.90*	0.03	0.25	0.67	0.05	0.43	0.51	0
Big Sheep/Lick	25	2.03	*3.2*	0.14	*0.90*	0.01	0.13	0.60	0.04	0.44	0.52	0
Grande Ronde												
Upper mainstem	87	1.33	*3.2*	0.17	*0.90*	0.06	0.25	0.58	0.06	0.62	0.32	0
Catherine	55	3.14	*3.2*	0.14	*0.90*	0.12	0.30	0.59	0.06	0.63	0.31	0
Lookingglass	71	1.00	*3.2*	0.19	*0.90*	0.08	0.30	0.59	0.06	0.63	0.31	0
Lostine	81	1.03	*3.2*	0.10	*0.90*	0.06	0.31	0.60	0.06	0.63	0.31	0
Minam	72	2.27	*3.2*	0.10	*0.90*	0.04	0.29	0.58	0.06	0.63	0.31	0
Wenaha	84	2.69	*3.2*	0.15	*0.90*	0.02	0.29	0.60	0.06	0.62	0.33	0
Methow	295	2.32	*2.2*	0.06	*0.90*	*0*	0.24	0.40	0.11	0.53	0.36	0
Entiat	123	1.39	*2.2*	0.12	*0.90*	*0*	0.29	0.47	0.10	0.60	0.29	0
Wenatchee	431	2.53	*2.2*	0.17	*0.90*	0.09	0.25	0.53	0.09	0.49	0.42	0
John Day												
Upper mainstem	89	1.04	*3.2*	*0.02*	*0.90*	0.01	0.25	0.80	0.02	0.91	0.07	0
Middle Fork	68	1.77	*3.2*	*0.02*	*0.90*	0.01	0.25	0.80	0.02	0.81	0.17	0
North Frk/Granite	360	1.33	*3.2*	*0.02*	*0.90*	0.01	0.25	0.80	0.03	0.73	0.24	0
Deschutes												
Warm Springs	327	1.08	--		*0.90*	0.27	0.15	0.87	0.05	0.74	0.21	0
Klickitat				0.10	*0.90*	0.31	0.18	0.88	0.07	0.26	0.65	0.02
Wind	316	--	--	0.33	*0.90*	0.19	0.15	0.87	0.04	0.59	0.37	0

[1] I = *Spawner index (redds or carcasses);*
i = Expansion factor for other spawning areas and nonpeak period sampling (were necessary);
k = Spawners per redd;
pH = Hatchery fraction;
pL = Prespawn survival;
pEB = Subbasin exploitation rate;
pEC = Mainstem exploitation rate;
pV = Mainstem conversion rate;
pG3,...6 = Proportion age 3, 4, 5, 6.

TABLE 5. Mean ± coefficient of variation (and range) for spawners, recruit and recruit per spawner numbers in aggregate and index populations of wild spring and summer chinook salmon in Idaho, Oregon, and Washington. Geometric rather than arithmetic means and standard deviations are presented for recruits per spawner. (Coefficient of variation is standard deviation divided by the mean and expressed as a percentage.)

Subbasin, population	N[1]	Spawners	Recruits to freshwater	Recruits per spawner
Aggregate				
Bonneville	53	59,031 ± 54% (15,949 - 135,831)	115,504 ± 64% (8,554 - 269,422)	1.7 ± 130% (0.3 - 13.7)
Snake Rive		19,611 ± 71% (3,733 - 51,058)	39,085 ± 93% 1,810 - 119,400	1.6 ± 120% (0.4 - 10.2)
Middle Fork Salmon				
Bear Valley/Elk	34	866 ± 76% (42 - 2,138)	2,968 ± 117% (33 - 13,469)	2.1 ± 160% (0.2 - 13.0)
Marsh	34	443 ± 76% (16 - 1259)	1,634 ± 113% (6 - 6,290)	2.1 ± 358% (0.1 - 39.1)
Sulphur	34	305 ± 84% (0 - 845)	1,104 ± 104% (9 - 3,974)	2.3 ± 306% (0.1 - 27.9)
South Fork Salmon				
Poverty Flat	34	810 ± 98% (76 - 3,735)	1,944 ± 127% (98 - 11,291)	1.9 ± 112% (0.2 - 8.4)
Johnson	34	322 ± 77% (36 - 1,114)	756 ± 103% (27 - 2,912)	1.8 ± 154% (0.2 - 11.9)
Imnaha				
Mainstem	41	1,110 ± 69% (169 - 3,462)	2,845 ± 90% (125 - 10,720)	2.0 ± 139% (0.3 - 16.3)
Big Sheep/Lick	27	201 ± 93% (0 - 644)	349 ± 140% (0 - 1,895)	0.9 ± 332% (0 - 13.7)
Grande Ronde				
Upper mainstem	32	394 ± 71% (3 - 1,118)	1,426 ± 118% (5 - 6,472)	1.9 ± 332% (0 - 30.9)
Catherine	38	601 ± 93% (32 - 2,501)	1,993 ± 96% (16 - 6,981)	2.3 ± 575% (0 - 71.2)
Lookingglass	34	243 ± 105% (0 - 1,234)	932 ± 106% (14 - 3,603)	2.6 ± 187% (0.2 - 17.1)
Lostine	36	260 ± 60% (26 - 705)	1,024 ± 107% (26 - 4,927)	2.5 ± 215% (0.2 - 24.1)
Minam	37	516 ± 94% (40 - 2,788)	1,504 ± 93% (30 - 5,242)	2.2 ± 223% (0.1 - 17.9)
Wenaha	30	636 ± 92% (37 - 2,087)	1,954 ± 149% (49 - 12,995)	1.7 ± 217% (0.2 - 17.2)
Methow	31	1,483 ± 62% (348 - 4,280)	7,033 ± 80% (159 - 19,465)	3.8 ± 123% (0.2 - 23.7)
Entiat	36	366 ± 65% (81 - 1,096)	1,479 ± 83% (99 - 5,162)	3.2 ± 171% (0.4 - 23.7)
Wenatchee	33	2,697 ± 48% (1,021- 5,930)	9,023 ± 81% (42 - 28,725)	2.4 ± 173% (0.1 - 16.6)
John Day				
Upper mainstem	32	267 ± 69% (13 - 823)	554 ± 50% (103 - 1,021)	2.5 ± 191% (0.3 - 20.4)
Middle Fork	32	374 ± 100% (22 - 1,908))	773 ± 67% (142 - 2,937)	2.5 ± 286% (0.2 - 39.3)
North Frk/Granite	27	1,559 ± 48% (301 - 2,995)	3,426 ± 59% (684 - 8,094)	2.1 ± 185% (0.5 - 17.2)
Deschutes				
Warm Springs	22	733 ± 57% (148 - 1,792)	2,617 ± 45% (502 - 5,878)	3.9 ± 146% (0.6 - 26.4)
Klickitat	25	243 ± 94% (39 - 1,108)	507 ± 75% (49 - 1,392)	2.1 ± 227% (0.2 - 21.6)
Wind	21	311 ± 144% (76 - 1,936)	225 ± 113% (3 - 1,216)	0.8 ± 212% (0 - 7.4)

[1] *Includes only years where both spawner and recruit estimates are available.*

TABLE 6. Correlations among brood year, spawners, recruits, Ln(recruits/spawner), distance of spawning grounds from the ocean (km), number of dams passed, stream length used for spawning (km), Bonneville Dam spring chinook count, and the Ice Harbor Dam spring chinook Count for pooled observations from each index population and year. For each comparison, values are listed in the following order: correlation coefficient, significance level, and sample size. Significant correlations at the $p < 0.05$ level are shaded.

Variable	Spawners	Recruits	Ln(R/S)	Ocean	Dam No.	Area	Count 1	Count 2
Year	-0.272 0.0001 832	-0.431 0.0001 718	-0.478 0.0001 706	-0.112 0.0011 844	-0.153 0.0001 844	0.051 0.1410 844	-0.305 0.0001 844	-0.469 0.0001 727
Spawners	1.000 0 832	0.583 0.0001 709	-0.066 0.0818 706	-0.078 0.0244 832	0.0232 0.5028 832	0.540 0.0001 832	0.242 0.0001 832	0.315 0.0001 725
Recruits		1.000 0 718	0.419 0.0001 706	-0.029 0.4337 718	0.126 0.0007 718	0.526 0.0001 718	0.002 0.9671 718	0.173 0.0001 612
Ln(R/S)			1.000 0 706	0.016 0.6751 706	0.028 0.4528 706	0.081 0.0312 706	-0.205 0.0001 706	-0.043 0.2944 607
Ocean				1.000 0 844	0.758 0.0001 844	-0.286 0.0001 844	-0.004 0.9135 844	0.012 0.7398 727
Dam No.					1.000 0 844	-0.060 0.0796 844	0.009 0.7896 844	0.011 0.7681 727
Area						1.000 0 844	-0.007 0.8203 844	0.004 0.9080 727
Count 1							1.000 0 844	0.826 0.0001 727
Count 2								1.000 0 727

TABLE 7. Correlations of spawner number with dam counts for each index population of wild spring and summer chinook salmon. Significant correlations at the $p < 0.05$ level are shaded.

Subbasin,	Bonneville count			Ice Harbor count		
population	*r*	*p*	N	*r*	*p*	N
Aggregate						
Bonneville	0.760	0.0001	58	0.711	0.0001	34
Snake River	0.636	0.0001	34	0.811	0.0001	34
Middle Fork Salmon						
Bear Valley/Elk	0.285	0.0783	39	0.586	0.0003	34
Marsh	0.387	0.0148	39	0.572	0.0004	34
Sulphur	0.508	0.0009	39	0.697	0.0001	34
South Fork Salmon						
Poverty Flat	0.146	0.3730	39	0.388	0.0233	34
Johnson	0.351	0.0286	39	0.633	0.0001	34
Imnaha						
Mainstem	0.646	0.0001	46	0.733	0.0001	34
Big Sheep/Lick	0.470	0.0067	32	0.610	0.0002	32
Grande Ronde						
Upper mainstem	0.508	0.0013	37	0.588	0.0002	34
Catherine	0.352	0.0207	43	0.570	0.0004	34
Lookingglass	0.426	0.0039	44	0.572	0.0004	34
Lostine	0.597	0.0001	44	0.641	0.0001	34
Minam	0.313	0.0435	42	0.640	0.0001	34
Wenaha	0.434	0.0051	40	0.727	0.0001	32
Methow	0.429	0.0090	36	0.581	0.0003	34
Entiat	0.392	0.0112	41	0.487	0.0035	34
Wenatchee	0.538	0.0005	38	0.674	0.0001	34
John Day						
Upper mainstem	0.097	0.5687	37	0.116	0.5149	34
Middle Fork	0.121	0.4765	37	0.027	0.8779	34
N. Fork/Granite	0.571	0.0002	37	0.708	0.0001	34
Deschutes						
Warm Springs	0.273	0.1679	27	0.255	0.1996	27
Klickitat	0.165	0.3847	30	0.327	0.0779	30
Wind	0.378	0.0571	26	0.296	0.1417	26

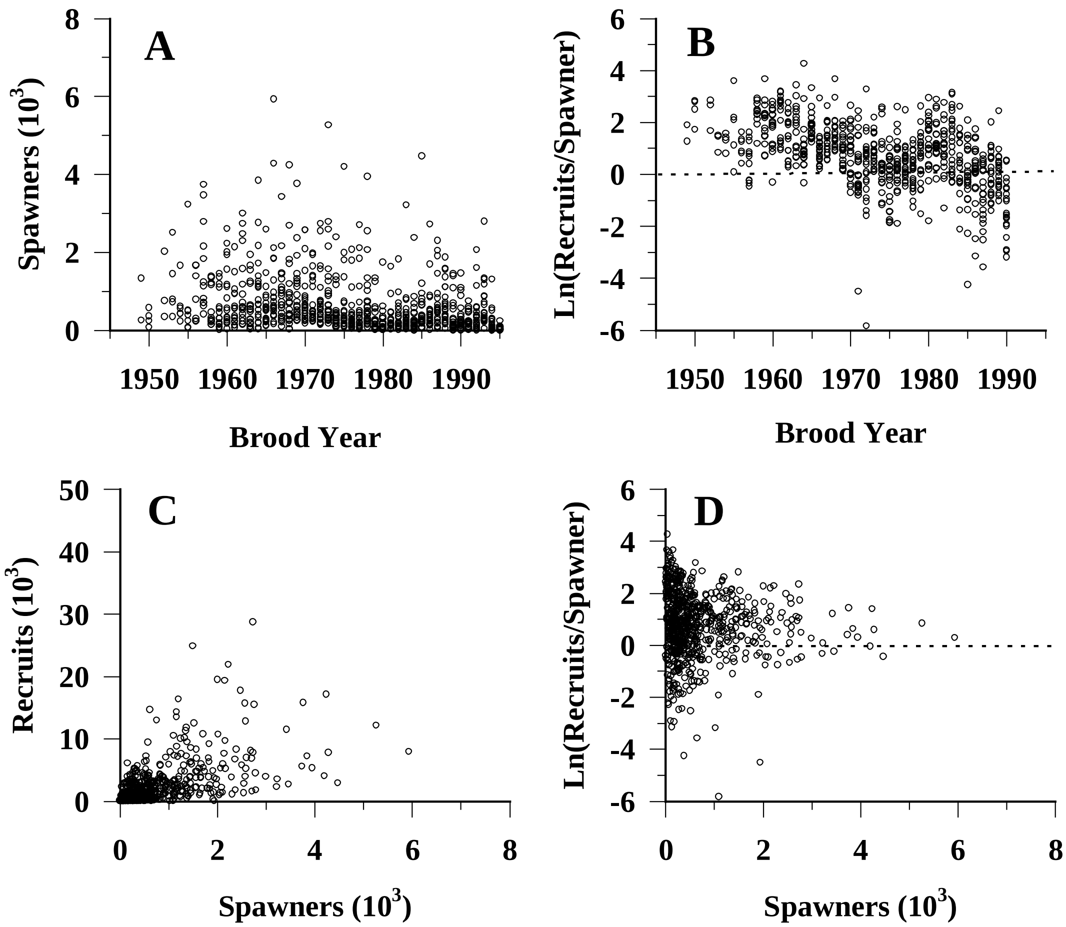

FIGURE 16. Spawners, recruits, and Ln(spawners/recruit) versus brood year and spawner number for pooled observations from all populations.

Discussion

This report presents the spawner-recruit data needed for detailed analysis of spring and summer chinook population productivity and survival rates throughout the interior Columbia basin. Populations were selected to represent upstream and downstream areas in the Columbia and Snake Rivers. Run reconstructions were limited to populations for which long-term, continuous inventory data were available although data are available for populations from areas of varying habitat quality.

We are unaware of the availability of continuous time series of population-specific data for years prior to those we report. Some data might exist in archived records for a few years in selected areas. However, incomplete data are of limited value in spawner-recruit run reconstructions which require continuous time series to estimate the recruits which return over several years for each spawner cohort. Additional run reconstructions might be feasible for other spring chinook salmon populations in the Salmon, Clearwater, and Tucannon rivers (Snake basin); McKenzie River (Willamette basin); and North Umpqua River (coastal Oregon) where extended time series of redd counts or dam counts are available. Run reconstructions are also feasible for natural fall chinook salmon and steelhead and for hatchery populations of salmon and steelhead.

Expansions of redd counts to spawner and recruit numbers are influenced by measurement error and uncertainty of assumptions regarding estimates of fish per redd, relative numbers in surveyed and unsurveyed areas, prespawning mortality rates, age composition, hatchery fish contributions, and conversion rates of adults returning through dams and fisheries. Constant pre-spawn mortality rates were applied to most populations for all years. Consequently, relative differences among stocks or years and between spawner and recruit numbers would be insensitive if expansion factors were not accurate because similar errors would have been applied to each population and year. The pre-spawning survival indices for Snake River wild spring and summer chinook from 1953-94 appear relatively stable (Petrosky 1995) especially compared to redd counts and harvest rates (Schaller et al. 1996). The assumption about constant rates would be more of a concern if redd counts, harvest rates, and adult passage conversion rates did not exhibit such high variability over the time series of interest. However, the lack of year or population specific expansion factors may result in underestimates of net variability among years or populations. Sensitivity analyses should be used to further explore the effects uncertainties in expansion factors on analyses of these data relative to the variability in measured parameters.

Reconstructions of spawner-recruit data represent substantial improvements over simple escapement trend analyses for evaluating historical changes in stock productivity and survival rates. Escapement trend analyses are confounded by density dependence in which moderate to high escapements produce proportionately fewer offspring because of carrying capacity limitations in tributary rearing habitats. For instance, declining escapements in the upper Snake River have resulted in an increase in smolts per spawner (Petrosky and Schaller 1996). Trend analyses based on escapement also fail to account for trends in harvest, adult passage mortality, and hatchery production. For instance, prior to 1970 Columbia River spring chinook salmon sustained large harvests and relatively stable escapements, whereas after 1970 effects of fisheries were minor. Significant increases in passage mortality and hatchery production have also been observed during the last 20-50 years. The logarithm of recruits per spawner better represents the multiplicative, log-normal nature of error terms in the data than a simple recruit per spawner index (Peterman 1981). Confounding effects of density dependence may also be evaluated by comparing the logarithm of recruits per spawner versus spawners in which case a slope of 0 indicates no density dependence. Effects of measurement error and annual variation in environmental conditions can be identified using the residuals in regressions of recruits versus spawners and can also be represented as Ln[(observed R/S)/(predicted R/S)] (Schaller et al. 1996, Deriso et al. 1996).

Interpretations or analyses of these data for other than productivity and survival rate analyses should also consider limitations specific to the data available for each population. For instance, spawning ground surveys for several populations were based on peak rather than total spawner counts. Peak surveys were timed for periods when maximum numbers of fish could be observed. More accurate estimates of redd numbers for each year are obtained from surveys later in the year after all fish had spawned, or from multiple surveys. Both types of surveys should provide valid estimates of relative spawner numbers but peak counts may underestimate total escapement. These considerations would be more important when determining spawning escapement goals or harvest rate targets.

Comparisons of pooled recruit per spawner data among areas or years like those included in this report, provide a general idea of the scope and nature of data but may obscure rather than clarify underlying relationships. For instance, declines in pooled average recruits per spawner may be driven by disproportionate changes in different areas or among only a few populations. Nonlinear relationships like Ricker stock-recruitment curves might not be apparent in linear correlations. Different time series available for each population confound time series comparisons and account for the significant correlation we observed between brood year and ocean distance to spawning grounds. (Longer time series of data were available in Snake River tributaries than in lower Columbia River tributaries). Thorough analysis of spawner-recruit data must be based on individual population responses stratified by time and area (e. g. Schaller et al. 1996, Deriso et al. 1996) . Analyses should also consider the underlying stock-recruitment relationships which were apparent even in our cursory examination of pooled data.

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